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TO
GEORGE TUDOR, ESQ.,
41, PORTMAN SQUARE, LONDON;
AND
AVENUE MATIGNON, No. 17, FAUBOURG ST. HONORE.

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DEAR SIR,

IN dedicating to you this Seventh Edition  
of my "Guide to Science," I am anxious no less to  
shew how highly I appreciate the encouragement you  
are accustomed to extend to Science and Literature,  
than to offer a slight testimony of my gratitude for  
much personal kindness and attention.

I have the honour to remain,

Dear Sir,

Your humble and faithful servant,

THE AUTHOR.

*July 21st, 1852.*



## Preface to the Seventh Edition.

No science is more generally interesting, than that which explains the common phenomena of life. We see that salt and snow are both white, a rose red, leaves green, and the violet a deep purple; but how few persons ever ask the reason why! We know that a flute produces a musical sound, and a cracked bell a discordant one—that fire is hot, ice cold, and a candle luminous—that water boils when subjected to heat, and freezes from cold; but when a child looks up into our face and asks us “why,”—how many times is it silenced with a frown, or called “very foolish for asking such silly questions!” The object of the present book is to explain above 2000 of these questions (which are often more easily asked than answered) in language so simple that a child may understand it, yet not so childish as to offend the scientific. In order to secure the strictest accuracy in the answers, the most approved modern authors have been consulted, and each edition has been submitted to the revision of gentlemen of acknowledged reputation for scientific attainments. Sincere thanks are due to the REV. A. BATH POWER, M.A., F.C.S., and to ROBERT JAMES MANN, Esq., M.R.C.S., of Aylsham, for their careful revision of the sixth, as well as for much useful information in some

of the former editions;\* the almost unparalleled success of this little volume, of which 44,000 copies have been printed since the year 1848, is an incontrovertible proof of its acceptability. The Author has spared neither labour nor expense to render his "Guide to the Scientific Knowledge of Things Familiar" instructive and amusing to the young, as well as to those of maturer life.

To teachers of schools it may be advisable to state, that, as every question has been again and again submitted to a most rigid investigation, no alteration of the text will be made in future editions; although such as may be needful, to render the book most generally useful, shall be given by annotations from time to time, as subsequent reprints may be demanded.

\* Mr. Simeon Simons, of Cromer, furnished some useful hints for the second edition; and C. Lloyd, Esq., of Oswestry, Salop, a judicious revision of the fifth edition.

A remarkable instance came before the Author a few months since of the statement made in the early part of this preface. The conversation was about smoke—why it was black, and not white, like the fine dust of lime. A little child who was present, asked, "Why is the kettle so black with smoke?" Her papa answered, "Because it has been on the fire;" "But" (urged the child) "what is the good of its being black?" The gentleman replied, "Silly child—you ask very foolish questions—sit down and hold your tongue." He might have read pp. 206, 207, 208, and answered the child more discreetly.

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## PART I.

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### HEAT.

#### INTRODUCTION.

Q. *What is*

A. That which produces the sensation of warmth.

Q. *How is this sensation produced?*

A. By a *subtile invisible stream*, which flows from some *hotter* substance, and produces on our nerves the sensation of warmth.

Q. *What is that "subtile invisible stream" called, which flows from the hotter substance?*

A. CALORIC. Caloric, therefore, is the *agent*, which produces the *sensation of warmth*.



Q. *What is the principal SOURCE of heat ?*

A. The Sun.

Q. *What other SOURCES of heat are there ?*

A. Electricity—Chemical Action—  
and Mechanical Action.

Q. *What are the principal EFFECTS of heat ?*

A. Expansion, Liquefaction, Vaporization, and Ignition.

## CHAPTER I.

Q. *What is the great natural SOURCE of heat ?*

A. The Sun.

Q. *Why do BURNING GLASSES set fire to substances submitted to their power ?*

A. Because, when the rays of the sun pass through the burning glass, they are bent towards one point, called the focus; in consequence of which, the light and heat at this point are very greatly increased.

Q. *Do the rays of the sun ever set fire to natural substances, WITHOUT the assistance of a burning glass?*

A. No. The rays of the sun, even in the torrid zone, are never hot enough to kindle natural substances, unless concentrated by a burning glass.

## CHAPTER II.

Q. *Name a SECOND source of heat.*

A. ELECTRICITY.

Q. *How is ELECTRICITY most commonly seen in NATURE?*

A. As lightning.

Q. *What is LIGHTNING?*

A. Lightning is accumulated electricity discharged from the clouds.

Q. *How many different kinds of lightning are there?*

A. As there are *two* kinds of electricity, so there are *two* kinds of lightning also.

Q. *What are the two kinds of ELECTRICITY called?*

A. The Vitreous and Resinous;—sometimes the Positive and Negative.

Q. *What causes the discharge of an ELECTRIC CLOUD?*

A. One kind of electricity rushing from a cloud, to unite itself with the other kind, either in another cloud, or in the earth.

Q. *What takes place when the two kinds of electricity MEET?*

A. They *neutralize* each other.

Q. *What is a THUNDER-STORM?*

A. The disturbance caused in the air, when successive discharges of accumulated electricity take place.

Q. *What are the SOURCES of the electricity which accumulates in the clouds?*

A. 1st—*Evaporation* from the earth's surface;  
c

2ndly—The *chemical changes* which take place in the earth's surface, and in the air; and

3rdly—Probably *friction* between currents of air of unequal temperature, passing by each other.

Q. *How HIGH are the LIGHTNING CLOUDS from the earth?*

A. Sometimes they are elevated 4 or 5 miles; and sometimes actually *touch the earth* with one of their edges: But they are rarely *discharged* in a thunder storm, when more than 700 yards above the surface of the earth.

Q. *How do such objects as trees, steeples, animals, &c. help the discharge of electric clouds?*

A. They reduce the distance between the electric cloud and the earth.

• Q. *Why is lightning sometimes FORKED?*

A. Because the flash is divided by certain terrestrial objects which it approaches,

Q. *Why is the flash sometimes ZIG-ZAG?*

A. Because lightning *condenses* the

air in the immediate advance of its path, and flies from side to side, in order to pass where there is the *least resistance*.

Q. *When is the flash STRAIGHT?*

A. When the *distance* through which the flash has to pass is *small*, so that the air in advance of its path is not sufficiently *condensed*, to cause it to fly from side to side.

Q. *What is SHEET LIGHTNING?*

A. The light of a flash *reflected* in the clouds, when the flash itself is concealed from view.

Q. *What OTHER form does lightning occasionally assume?*

A. It sometimes assumes the *globular* form, and sometimes what is called the *brush* form.

This *brush* discharge is what is called "Castor and Pollux," or "Elmos-fire." Dr. Faraday says, it is a discharge between the air and some conductor.

The cause of *globular* lightning is not known.

Q. *Why does lightning produce a flash when it passes through the AIR?*

A. Because the air, being a *non-conductor*, cannot convey it in an invisible form.

Q. *Does lightning never produce a flash when it passes through a CONDUCTOR?*

A. No. Electricity passes through all *conductors* in a quiet and invisible form.

Q. *Why does LIGHTNING sometimes KILL men and beasts?*

A. Because (when the electric current passes through a man or beast) it produces so *violent an action upon the nerves*, as to destroy life.

Q. *WHEN is a person struck DEAD by lightning?*

A. Only when his body forms a part of the *lightning's path*; i. e. when the electric fluid, (in its way to the earth) actually passes *through his body*.

Q. *Why are animals sometimes HURT by lightning, and not KILLED?*

A. Because the amount of electric fluid which passes through their bodies,

A. Because the storm is *far distant*, and the sound of the thunder indistinct.

Q. *How is the sound of thunder affected by LOCAL circumstances?*

A. The *flatter* the country, the more unbroken the peal. *Mountains* serve to *break* the peal, and make it harsh and irregular.

Q. *What is the cause of ROLLING THUNDER?*

A. The echoes of the peal reverberating amongst masses of cloud and terrestrial objects.

Q. *Why is a flash of lightning generally followed by POURING RAIN?*

A. Because it produces a change in the *physical condition* of the air, rendering it unable to hold so much water in solution as it could before; in consequence of which, a part is given off in heavy rain.

Q. *Why is a flash of lightning generally followed by a GUST OF WIND?*

A. Because the *physical condition* of

*the air* is disturbed by the passage of the lightning, and wind is the result of this disturbance.

Q. *Why is there no thunder to what is called*  
SUMMER LIGHTNING?

A. Because the lightning-clouds are *so far distant*, that the sound of the thunder is *lost*, before it reaches the ear.

Q. *Do* THUNDER-BOLTS *ever drop from the clouds?*

A. No; the notion of thunder-bolts arises from the *globular* form which lightning sometimes assumes.

Q. *Why is* THUNDER *often several moments*  
AFTER *the flash?*

A. Because it has a long way to come. Lightning travels nearly *a million* times faster than thunder; if, therefore, the thunder has *a long way to come*, it will not reach the earth till a considerable time *after the flash*.

Q. *Why can we tell the* DISTANCE *of a thunder-*  
*cloud, by observing the interval which elapses between*  
*the flash and the peal?*



A. Because the flash is *instantaneous*; but thunder will take a whole *second of time* to travel 380 yards: hence, if the flash be 5 seconds before the thunder, the cloud is 1900 yards off.

The speed of lightning is so great, that it would go 480 times round the earth in one minute: whereas thunder would go scarcely 13 miles in the same space of time.

Q. *What PLACES are most DANGEROUS during a STORM?*

A. It is very dangerous to be near a tree, or lofty building; a river, or any running water.

Q. *Why is it DANGEROUS to be NEAR a TREE, or lofty building, during a thunder storm?*

A. Because a tall object (like a tree or spire) will frequently *discharge* a lightning-cloud; and if any one were standing near, the lightning might diverge from the tree, and pass through the fluids of his body.

Q. *How can a TREE or SPIRE, DISCHARGE a lightning-cloud?*

A. A lightning-cloud (floating over a plain) may be *too far off* to be dis-

charged by it; but, as a tree or spire would *shorten* this distance, it might no longer be too far off to be discharged.

For example—If a lightning-cloud were 700 yards above a conductor, it would be *too far off* to be discharged:—but a tree or spire 50 yards high, would make the cloud only 650 yards off a conductor; in consequence of which, the cloud might be instantly *discharged*.

Q. *Why would lightning fly from a tree or spire, into a MAN standing near?*

A. Because the electric fluid always chooses for its path the *best conductors*; and, if the human fluids proved the better conductor, would pass through a man standing near the tree, rather than down the tree itself.

There would be no danger if the tree or spire were made of *metal*; because metal is a better conductor than the human fluids.

Q. *Does lightning go through the inside, or down the outside of a tree?*

A. It runs down a tree between the bark and the wood, where the sap is most abundant.

Q. *Why does lightning take its course between the bark and wood of a tree?*

A. Because it makes choice of the

*best conductors* : and this part of a tree is best suited for a conductor.

Q. *Why does lightning pass through the INSIDE of a man ?*

A. Because the *fluids* of the human body make a better conductor than the *skin* ; therefore, lightning passes *through* a man, and not down his skin.

Q. *Why is it DANGEROUS to be near water during a thunder-storm ?*

A. Because water is a good conductor ; and lightning always takes in its course the *best conductors*.

Q. *Why is it dangerous for a man to be NEAR WATER, in a thunder-storm ?*

A. Because the *height of a man* may be sufficient to discharge a cloud : and (if there were no *taller* object nigh) the lightning might make the *man* its conductor to the water.

See the first note on p. 13.

Q. *Why is it dangerous to remain in a CHURCH STEEPLE during a thunder-storm ?*

A. Because the church steeple is a tall object, and composed of imperfect conductors.

Q. *Are IRON houses dangerous during a storm ?*

A. No. Because the metal walls will convey the electric fluid harmlessly to the ground.

Q. *What PARTS of a building should be avoided during a thunder-storm ?*

A. Those connected with the roof by a continuous line of conducting substances, but which have no outlet of conductors downwards.

Such as the *stove*, with its column of *ascending smoke*.

Q. *Why has the stove no outlet of conductors downwards ?*

A. Because it stands upon stone, and is embedded in bricks; both of which are non-conducting substances.

Q. *Would lightning leave the stove and strike a person standing near it ?*

A. It might, if by this means a more direct passage were offered to some conducting substances.

Q. *When does lightning pass FROM THE EARTH to the CLOUDS?*

A. One kind of electricity always passes *upwards to the clouds*, whenever the *other* kind passes *downwards to the earth*.

Q. *Which kind of electricity passes DOWNWARDS, from the clouds to the earth?*

A. Generally the *vitreous*, but occasionally the *resinous*.

Q. *Which kind of electricity passes UPWARDS from the earth to the clouds?*

A. Generally the *resinous*, but occasionally the *vitreous*.

Q. *Why is VITREOUS electricity so called?*

A. Because it was first procured by rubbing glass.

*Vitreous* is a Latin word, meaning "of the nature or property of glass."

Q. *Why is RESINOUS electricity so called?*

A. Because it was first procured by rubbing resinous substances.

Q. *Are there any other names by which the vitreous and resinous electricities are also known?*

A. They are sometimes called *positive and negative electricities*.

So called by Dr. Franklin and his disciples.

Q. *Why were the terms positive and negative employed to express conditions of electricity?*

A. Because the early electricians conceived that there were not two *kinds*, but only two *states* of electricity; the one marked by a superabundance, and the other by a deficiency, of one and the same fluid.

Q. *Why is it DANGEROUS to lean AGAINST A WALL during a thunder-storm?*

A. Because the electric fluid will sometimes run down a *wall*; and would leave the *wall* to run down the man, because he is a better conductor.

Q. *Why is it dangerous to RING a BELL during a thunder-storm?*

A. Because bell-wire is an *excellent conductor*; and the electric fluid, passing down the wire, might run through our hand, and injure us.

Q. *Why would the lightning run through a man touching a bell-handle?*

A. Because the human body is a better conductor than the *wall* (between the bell-handle and the floor); and as

lightning always chooses the *best* conductor for its path, it would (in this case) pass through the *man*, and injure him.

Q. *Why is it dangerous to BAR a SHUTTER during a thunder-storm?*

A. Because the iron shutter-bar is an *excellent conductor*; and the electric fluid might run from the bar *through the person touching it*, and injure him.

Q. *Why is it dangerous to be in a CROWD during a thunder-storm?*

A. For two reasons: 1st—Because a mass of people forms a larger, and a better conductor, than an individual: and

2ndly—Because the *vapour* arising from a crowd *increases* the conducting power of the air above.

Q. *Why is a MASS of bodies a better conductor than a single body?*

A. As *each* living body is a *conductor of electricity*, a connected mass of people would afford a readier passage for a large quantity of electricity, than a single individual.

Q. *Why is danger increased by the VAPOUR which rises from a crowd?*

A. Because *vapour* is a conductor, and would lead the electricity down towards the crowd.

Q. *Why is a THEATRE dangerous during a thunder-storm?*

A. Because the *crowd*, and *great vapour* arising from so many living bodies, render it an *excellent conductor of lightning*.

Q. *Why is a FLOCK of sheep in greater danger than a smaller number?*

A. 1st—Because *each* sheep is a conductor of lightning, and the conducting power of the *flock* is increased by its numbers: and

2ndly—The *vapour* arising from a flock of sheep *increases the conducting power* of the air above.

Q. *Why is a HERD of cattle in danger during a storm?*

A. 1st—Because the *number* of living bodies increases the conducting power of their *animal fluids*: and



2ndly—The *vapour* arising from a herd increases its conducting power.

Q. *If a person be ABROAD in a thunder-storm, what place is the safest?*

A. Any place about 20 or 30 feet from some tall tree or building; if it be not near to running water.

Q. *Why would it be safe to stand 20 or 30 feet from some tall tree, in a thunder-storm?*

A. Because the lightning would always choose the *tall tree* as a conductor; and we should not be sufficiently *near* the tree, for the lightning to diverge from it to *us*.

Q. *If a person be in A CARRIAGE in a thunder storm, in what way can he travel most SAFELY?*

A. He should not lean *against* the carriage; but sit upright without touching any of the four sides.

Q. *Why should not a person lean AGAINST the carriage in a storm?*

A. .Because the electric fluid might run down the sides of the carriage; and (if a person were leaning against them) would make choice of *him* for a conductor, and perhaps destroy life.

Q. *Why is the MIDDLE of a room more safe than any other part of it, in a thunder-storm ?*

A. Because the lightning (if it struck the room at all) would come down the chimney or walls of the room; and therefore, the further distant from these the better.

Q. *Why is a MATTRESS, BED, or HEARTH-RUG a security, to a certain extent, against injury from lightning ?*

A. Because they are all non-conductors; and, as lightning always makes choice of the best conductors, it would not choose for its path such things as these.

Q. *Is an IRON BEDSTEAD dangerous in a storm?*

A. No; for it is so good a conductor that the electricity would pass down it in preference to the animal fluids.

Q. *Is a man in METAL ARMOUR in danger from lightning ?*

• A. No; for the armour is so good a conductor, that the electricity would pass along it in preference to the fluids of the human body.

Q. *Why do PIECES OF METAL such as keys, watches, rings, and brooches carried about the person increase the danger from lightning ?*

A. Because they offer strong inducement to the electricity to *take them in its path*, but do not extend far enough to *conduct it to the earth*.

Q. *Is it better to be wet or dry during a storm?*

A. To be *wet*: if a person be in the open field, the best thing he can do, is to stand about 20 feet from some tree, and get *completely drenched to the skin*.

Q. *Why is it better to be WET than dry in a storm?*

A. Because *wet clothes* will conduct the discharge harmlessly over the *surface* of the body.

Dr. Franklin found that he could not destroy a *wet* rat by electricity artificially accumulated, although he could a *dry* one.

Q. *What is the SAFEST thing a person can do to avoid injury from lightning?*

A. To draw his bedstead into the middle of his room, commit himself to the care of God, and go to bed; remembering that our Lord has said, "The very hairs of your head are all numbered."

N. B. No great danger needs really to be apprehended from lightning, if you avoid taking your position near tall trees, spires, or other elevated objects.

Q. *What is a LIGHTNING-CONDUCTOR?*

A. A metal rod fixed in the earth, running up the whole height of a building, and rising in a point above it.

The point of a conductor should rise well into the air, and be made triangular, like a bayonet.

Q. *What metal is the best for this purpose?*

A. Copper.

Q. *Why is COPPER better than iron?*

A. 1st—Because it is a better conductor than iron, and therefore not so easily fused by lightning: and

2ndly—It is not so much injured by weather.

N. B. Electricity does not produce heat when it passes through a good conductor; heat only appears when the free passage of the electric matter is obstructed.

The following numbers express the relative value of several kinds of metal, in conducting electricity:

Lead 1.—Iron  $2\frac{2}{3}$ .—Zinc 4.—Copper 12. Copper is, therefore, 5 times better as a conductor of lightning than iron.

Q. *What is the USE of a lightning conductor?*

A. It furnishes a path for the passage of lightning; which will run down a metal rod rather than the walls of a building, because metal is a better conductor.

Q. *How FAR does the beneficial influence of a lightning-conductor extend?*

A. This has not been accurately determined; but one conductor will sufficiently protect a building of ordinary extent.

Q. *Why are not lightning-conductors more generally used?*

A. Because many accidents have arisen from conductors of defective construction.

Q. *How can lightning-conductors be productive of HARM?*

A. If the rod be broken by weather or accident, the electric fluid (being obstructed in its path) may damage the building.

Q. *If the rod be unbroken, is any evil to be apprehended from it?*

A. Not if the rod be thick enough to conduct the *whole* current to the earth: But if too small for this purpose, the lightning will *fuse* the metal, and injure the building.

If copper be employed, the diameter of the rod should be half an inch. An iron rod should be somewhat thicker.

Q. *How does LIGHTNING sometimes KNOCK HOUSES and churches?*

A. The steeple, or chimney is first struck; the lightning then darts to the iron bars and cramps, employed in the building; and (as it darts from bar to bar) shatters the bricks and stones, which oppose its progress.

Q. *Tell me how St. Bride's Church (London) was nearly destroyed by lightning, about 100 years ago.*

A. The lightning first struck the metal vane of the steeple, and ran down the rod; it then darted to the iron cramps, employed to support the building; and (as it flew from bar to bar) smashed the stones which lay between.

Q. *Why did the lightning fly about from place to place, and not pass down in a straight course?*

A. Because it always takes in its course the *best conductors*; and will fly both right and left, in order to reach them.

Q. *Why does LIGHTNING turn milk SOUR?*

A. Because it produces a disturbance in the *electrical condition* of milk which causes the complex *organic body* to decompose, and consequently to *turn sour*.

Q. *Is NITRIC ACID ever formed in the air by lightning?*

A. Yes. The chemist, Liebig, found nitric acid in 17 specimens of rain water, *collected immediately after thunder-storms*: Although in 58 specimens, collected at *other times*, no traces could be found.

Q. *What is nitric acid?*

A. The gases, oxygen and nitrogen, chemically united together, in the proportions of one part of the former to five parts of the latter.

Q. *Where do the oxygen and nitrogen come from, that are formed into nitric acid by lightning?*

A. The air itself is composed of oxygen and nitrogen *mechanically mingled* together. The passing lightning has the power of making a portion of these combine *chemically*.

Q. *What is the difference between chemical union and mechanical admixture?*

A. In a *chemical* union, the properties of the mingled bodies are altered. In a *mechanical* admixture, they are not.

Different coloured sands shaken together in a bottle mix mechanically. Water poured on quick-lime unites with it chemically.

Q. *Why does lightning sometimes produce a sulphurous smell in the air?*

A. Because some vapour, possessing a sulphurous odour, is formed or brought from the higher regions of the air, by the operation of lightning.

Some chemists have conceived it to be merely nitrous acid gas, a combination of oxygen and nitrogen, possessing a smaller proportion of the latter element than nitric acid.

Q. *Why does LIGHTNING turn BEER SOUR, although contained in a close cask?*

A. Because, if beer be *new* and the process of fermentation incomplete, lightning so *accelerates* the process, as to turn the sugar into *acetic acid* before it has passed through the intermediate state of *al'cohol*.

Q. *Why is NOT OLD BEER and strong PORTER made SOUR by lightning?*

A. Because the *fermentation is more complete*; and, therefore, is less affected by electrical influence.

Q. *Why is METAL sometimes FUSED by lightning?*

A. Because the surface of the metal is *too small* to afford a path for the electric current.



Q. *Why does LIGHTNING PURIFY the AIR?*

A. For two reasons: 1st—Because the electric fluid produces nitric acid in its passage through the air: and

2ndly—Because the agitation of the storm *stirs up the air*.

The “nitric acid” is produced by the *combination* of some portions of the oxygen and nitrogen of the air.\*

Q. *How does the production of nitric acid PURIFY the air?*

A. Nitric acid acts very powerfully in *destroying the exhalations*, which arise from putrid vegetable and animal matters.

Q. *Why is LIGHTNING more common in SUMMER and AUTUMN, than in spring and winter?*

A. Because the heat of summer and autumn produces *great evaporation*; and the conversion of *water into vapour* always develops *electricity*.

Q. *Why does a THUNDER-STORM generally follow very dry weather?*

A. Because *dry air* (being a non-conductor) will not relieve the clouds of their electricity; so the fluid accumulates, till the clouds are discharged in a storm.

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\* The oxygen and nitrogen are not *combined*, but simply *mixed*, in the ordinary air; but lightning causes some portions of the mixed elements to *combine*.

*Q. Why does a THUNDER-STORM rarely succeed wet weather?*

A. Because moist air or falling rain (being a conductor) carries down the electric fluid gradually and silently to the earth.

*Q. Why is ELECTRICITY excited by FRICTION?*

A. Because friction disturbs the equilibrium of the two fluids; which remain no longer quiescent, but separate from each other.

When this disturbance takes place, the two fluids are said to be in "a free state."

*Q. Why is a TREE sometimes scorched by lightning, as if it had been set on fire?*

A. Because it obstructed the course of the electric fluid, in its way to the earth; and when electricity is obstructed in its path, it gives out great heat.

This would be especially the case in old knarled oaks, and dry sapless trunks, which would be but very imperfect conductors.

*Q. Why is the BARK of a TREE often ripped quite off by a flash of lightning?*

A. Because some obstruction is offered to the electric fluid in its passage down the tree, and the bark is ripped off by the mechanical violence of the resisted flash.

Q. *Why are BOUGHS of TREES broken off by lightning?*

A. Because the *mechanical force* of lightning is very great; and, as the boughs of a tree are imperfect conductors, they will often be broken off by this force.

Q. *Why is an electric shock felt MOST at the ELBOW JOINT?*

A. Because the path of the fluid is *obstructed by the joint*: The shock (felt at the elbow) is caused by the fluid *leaping from one bone to another*.

Q. *Is electricity accompanied with any ODOUR?*

A. Yes; near a large electrical machine in good action, there is always a peculiar odour, resembling *sulphur* and *phosphorus*; this odour is called "OZONE."

Pronounce O-ZONE, in two syllables.

Q. *Has this peculiar odour, called "OZONE," been observed in thunder-storms?*

A. Yes; at times the *sulphurous* odour prevails, and sometimes the *phosphoric*.

If the gaseous body disengaged by lightning, reaches us in a *concentrated* form, the odour is *SULPHUROUS*; if in a *diluted* form, it is *PHOSPHORIC*.

Q. *What are FUL'GURITES?*

A. Hollow tubes produced in sandy soils by the action of lightning.

Q. *How does lightning produce fulgurites ?*

A. When it enters the earth, it fuses the flinty matter of the soil into a vitreous (or glassy) substance, called a fulgurite.

Q. *How does lightning sometimes affect the character of IRON and STEEL ?*

A. Bars of iron and steel are sometimes rendered *magnetic* by lightning.

Q. *Give an instance of the magnetic effects of lightning.*

A. Sometimes it will *reverse* the magnetic needles of the electric telegraph, and sometimes *destroy* their magnetism altogether.

Q. *What is meant by the magnetic needles being REVERSED ?*

A. That part of the needle which ought to point towards the *north*, is made to point towards the *south* ; and that part which ought to point *south*, is made to point towards the *north*.

Q. *How does lightning act upon the magnetic needles of the electric telegraph ?*

A. The electric fluid is conveyed along the *conducting* wires round the telegraphic needles.

## CHAPTER III.

Q. *What is the THIRD source of heat ?*

A. CHEMICAL ACTION.

Q. *What is meant by chemical action being the source of heat ?*

A. Many things, when their chemical constitution is changed, (either by the abstraction of some of their gases, or by the combination of others not before united) evolve *heat*, while the change is going on.

Q. *Explain by illustration what you mean.*

A. Water is cold and sulphuric acid is cold; but if these two *cold* liquids be mixed together, they will produce *great heat*.

Q. *Why does COLD WATER, poured on LIME, produce great heat ?*

A. Because the water *unites* with the lime; and becoming *solid*, gives off that heat, which was necessary to retain it in a fluid state.

N. B. Heat is always *evolved*, when a fluid is converted into a *solid* form. Heat is always *absorbed*, when a solid is changed into a *liquid* state.

Q. *Where does the heat come from ?*

A. It was in the water before; but was in a *latent state*.

Q. *Was there heat in the cold water and lime, before they were mixed together?*

A. Yes. *All* bodies contain heat; the coldest ice, as well as the hottest fire.

Q. *Is there HEAT even in ICE?*

A. Yes; but it is *latent* (i. e. not perceptible to our senses).

Latent, from the Latin word, *Lateo*, (to lie hid.)

Q. *How do you KNOW there is heat, if you cannot PERCEIVE it?*

A. Thus:—Ice is  $32^{\circ}$ \* of temperature, by the thermometer; but if a pound of ice be melted over a fire, (although  $140^{\circ}$  of heat are absorbed by the process), it will feel no *hotter* than it did before.

i. e. it will be only  $32^{\circ}$ , and not  $172^{\circ}$  by the thermometer.

Q. *What becomes of the  $140^{\circ}$  of heat which went into the ice to melt it?*

A. They are hidden in the water; or stored up in a *latent state*.

Q. *How much heat may be thus secreted or made latent?*

A. The quantity varies in different substances; but in *water*, as much as  $1140^{\circ}$  of heat may remain latent.

\* i. e.  $32$  degrees;  $140^{\circ}$ , i. e.  $140$  degrees, &c.

Q. *How can 1140° of heat be added to water, without being perceptible to our feelings?*

A. 1st—140° of heat are hidden in water, when *ice is melted* by the sun or fire: and

2ndly--1000° more are secreted, when water is converted into *steam*. Thus, before *ice* is converted into steam, 1140° of heat become *latent*.

One pint of boiling water, (212° according to the thermometer) will make 1800 pints of steam; but the steam is no hotter to the touch than boiling water, both are 212°; therefore, when water is converted into steam, 1000° of heat become latent. Hence, before ice is converted into steam, it must absorb 1140° of latent heat.

Q. *How can we be made to FEEL the heat of ICE or snow?*

A. Into a pint of snow put half as much *salt*; then plunge your hands into the liquid; and it will feel so intensely cold, that the snow itself will seem *warm* in comparison to it.

Q. *Is SALT and SNOW really COLDER than snow?*

A. Yes, many degrees; and by dipping your hand into the mixture *first*, and into snow *afterwards*, the snow will seem to be comparatively warm.

Q. *What is FIRE?*

A. Heat and light, produced by the combustion of inflammable substances.

Q. *How is HEAT evolved by combustion?*

A. By *chemical action*. As latent heat is liberated, when water is poured upon lime, by chemical action; so latent heat is liberated in *combustion*, by chemical action also.

Q. *What CHEMICAL ACTION takes place in combustion?*

A. The *elements of the fuel* separate from each other, and combine with the *oxygen of the air*.

Q. *What is meant by the "ELEMENTS of FUEL"?*

A. The chemical elements of which the fuel is composed, named carbon, hydrogen, and oxygen.

Q. *What are the ELEMENTS of atmospheric AIR?*

A. • Oxygen and nitrogen, *mixed* together in the following proportions:—Four gallons of nitrogen and one of oxygen will make 5 gallons of common air.

Air contains small quantities of carbonic acid gas and ammonia, as also vapour of water.

Q. *What is CARBON?*

A. The solid part of fuel. Carbon



abounds in all animal bodies, earths, and in some minerals.

Q. *Mention some different species of CARBON.*

A. Common charcoal, lamp-black, coke, and the diamond.

Q. *What is HYDROGEN?*

A. An inflammable gas. The gas used in our streets is hydrogen *driven out of coals by heat.*

Coal gas (more correctly speaking) is carburetted hydrogen, i. e. carbon and hydrogen. *See p. 293.*

Q. *What are the characteristics of hydrogen gas?*

A. 1st—It is the *lightest* of all known substances:

2ndly—It will burn immediately it is ignited: and

3rdly—A lighted candle (immersed in it) will be instantly extinguished.\*

\* Hydrogen gas may be made thus:—Put some pieces of zinc or iron filings into a glass: pour over them a little sulphuric acid (vitriol), diluted with twice the quantity of water; then cover the glass over for a few minutes, and hydrogen gas will be given off.

#### EXPERIMENTS.

If a flame be put into the glass, an EXPLOSION will be made.

If the experiment be tried in a phial, which has a piece of tobacco pipe run through the cork, and a light be held for a few moments to the top of the pipe, FLAME will be made.

If a balloon be held over the phial, (so that the gas can inflate it), the balloon will ascend in a very few minutes.

**Q.** *What is OXYGEN?*

**A.** A gas, much heavier than hydrogen: it gives brilliancy to flame, and is essential to animal life.\*

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\* Oxygen gas is much more troublesome to make than hydrogen. The *cheapest* plan is to put a few ounces of manganese (called the black oxide of manganese) into an iron bottle, furnished with a bent tube: set the bottle in a fire till it becomes red hot, and put the end of the tube into a pan of water. In a few minutes, bubbles will rise through the water: these bubbles are oxygen gas.

These bubbles may be collected thus:—Fill a common bottle with water; hold it inverted over the bubbles which rise through the pan, but be sure the mouth of the bottle be held *in the water*. As the bubbles rise into the bottle, the water will run out; and when all the water has run out, the bottle is full of gas. Cork the bottle while the *mouth remains under water*: set the bottle on its base; cover the cork with lard or wax, and the gas will keep till wanted.

N.B. The *quickest* way of making oxygen gas, is to rub together in a mortar half an ounce of oxide of copper, and half an ounce of chlorate of potassa. Put the mixture into a common oil flask, furnished with a cork which has a bent tube thrust through it. Heat the bottom of the flask over a candle or lamp; and when the mixture is red hot, oxygen gas will be given off. Note—the tube must be immersed in a pan of water, and the gas collected as before.

(Chlorate of potassa may be bought at any chemist's; and oxide of copper may be procured by heating a sheet of copper red hot, and when cool, striking it with a hammer; the scales that peel off, are oxide of copper.)

**Exp.** Put a piece of red-hot charcoal (fixed to a small piece of wire) into your bottle of oxygen gas; and it will throw out most dazzling sparks of light.

Blow a candle out; and while the wick is still red, hold the candle (by a piece of wire) in the bottle of oxygen gas; the wick will instantly ignite, and burn brilliantly.

(Burning sulphur emits a *blue* flame, when immersed in oxygen gas.)

Q. *What is NITROGEN?*

A. An invisible gas, which is the principal ingredient of common air; it abounds in animal substances: The following are its characteristics;

1. It will not burn;
2. It will not support combustion; and
3. An animal cannot live in it.

Nearly 4 gallons out of every 5 of common air, are nitrogen gas.\*

Q. *Why is there so MUCH nitrogen in the air?*

A. In order to *dilute* the oxygen. If the oxygen were not thus diluted, fires would burn out too quickly, and life would be too rapidly exhausted.

Q. *What three elements are employed in making a common FIRE?*

A. Hydrogen gas, carbon, and oxygen gas: The two former in the *fuel*; and the last in the *air*, which surrounds the fuel.

Q. *What causes the combustion of the fuel?*

A. The hydrogen gas of the fuel

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\* Nitrogen gas may easily be obtained thus:—Put a piece of burning phosphorus on a little stand, in a plate of water; and cover a bell glass over it. (Be sure the edge of the glass stands *in the water*.) In a few minutes the *oxygen* of the air will be taken up by the burning phosphorus; and the nitrogen alone will be left in the bell glass.

(N.B. The white fume which will arise and be absorbed by the water in this experiment, is phosphoric acid; i.e. phosphorus combined with oxygen of the air.)

(being set free and excited by a match) *unites* with the *oxygen* of the air, and makes a yellow flame; this flame heats the *carbon* of the fuel, which unites with more oxygen, and produces *carbonic acid gas*.

The gas of the fuel is carburetted hydrogen. The flame of pure hydrogen is pale *blue*—of carburetted hydrogen *yellow*.

Q. *What is CARBONIC ACID GAS?*

A. Carbon (or charcoal) combined with oxygen gas.

Q. *Why does FIRE produce HEAT?*

A. Because it liberates *latent heat* from the air and fuel, by chemical action.

Q. *What CHEMICAL CHANGES in air and fuel are produced by COMBUSTION?*

A. 1st—*Some* of the oxygen of the air, combining with the *hydrogen* of the fuel, condenses into *water*: and

2ndly—*Some* of the oxygen of the air, combining with the *carbon* of the fuel, forms *carbonic acid gas*.

Q. *Why is a FIRE (after it has been long burning) RED HOT?*

A. Because the whole surface of the coals is so thoroughly heated, that every part of it is undergoing a rapid union with the oxygen of the air. - -

Q. *In a BLAZING fire, why is the UPPER surface of the COALS BLACK, and the LOWER surface RED?*

A. Because carbon (being solid) requires a great degree of heat to make it unite with the oxygen of the air. In consequence of which, the hot *under* surface of coals is frequently *red* from its union with oxygen, while the cold *upper* surface remains *black*.

Q. *Which burns the more quickly, a BLAZING fire, or a RED HOT one?*

A. Fuel burns quickest in a *blazing* fire.

Q. *Why do BLAZING COALS BURN QUICKER than red hot ones?*

A. Because the inflammable *gases* of the fuel (which are then *escaping*) greatly assist the process of combustion.

Q. *Why do the coals of a CLEAR BRIGHT fire burn out more slowly, than blazing coals?*

A. Because most of the *inflammable gases*, and much of the *solid fuel*, have been consumed already; so that there is less food for combustion.

Q. *What is SOOT?*

A. *Unconsumed* carbon of the fuel

separated from the solid mass, and carried up the chimney by currents of hot air,

Q. *What is SMOKE?*

A. Unconsumed volatile matters, separated from the fuel, and carried up the chimney by currents of hot air.

This volatile matter consists of visible vapour, various gaseous exhalations, and minute pieces of carbon.

Q. *Why is there MORE SMOKE when COALS are FRESH added, than when they are red hot?*

A. Because *more carbon* and volatile matters are *separated* from the fuel than can be *reduced by combustion*; and the surplus flies off in smoke.

Q. *Why is there so LITTLE SMOKE with a RED HOT FIRE?*

A. Because the *entire surface* of the coals is in a *state of combustion*; and, as very little of the escaping carbon remains unconsumed, there is but little smoke.

Q. *Why are there DARK and BRIGHT SPOTS in a CLEAR cinder fire?*

A. Because the *intensity* of the combustion is *greater in some parts* of the fire, than it is in *others*.

Q. *Why is the intensity of combustion in a common fire so UNEQUAL?*

A. Because air flies to the fire in various and unequal currents.

Q. *Why do we see all sorts of GROTESQUE FIGURES in hot COALS?*

A. Because the *intensity* of combustion is *unequal*, owing to the gusty manner in which the air flies to the fuel: And the various shades of red, yellow, and white heat (mingling with the black of the unburnt coal), produce strange and fanciful resemblances.

Q. *Why does PAPER BURN more readily, than wood?*

A. Because it is of a *more fragile texture*; and, therefore, its component parts are more easily heated.

Q. *Why does WOOD BURN more readily, than coal?*

A. Because it is not so *solid*; and, therefore, its elemental parts are more easily separated, and made hot.

Q. *When a FIRE is LIGHTED, why is PAPER laid at the BOTTOM, against the grate?*

A. Because paper (in consequence

of its fragile texture) very readily catches fire.

Q. *Why is wood laid on the top of the paper ?*

A. Because wood (being more *substantial*) burns longer than paper; and, therefore, affords a *longer* contact of *flame* to heat the coals.

Q. *Why would not paper do WITHOUT wood ?*

A. Because paper burns out so *rapidly*, that it would not afford sufficient *contact of flame* to heat the coals to combustion.

Q. *Why will not wood do WITHOUT shavings, straw, or paper ?*

A. Because wood is too *substantial* to be heated into combustion by the feeble flame issuing from a *match*.

Q. *Why would not the paper do as well, if placed on the top of the coals ?*

A. Because every blaze *tends upwards*; if, therefore, the paper were placed on the *top* of the coals, its blaze would afford *no contact of flame* to the fuel lying *below*.

Q. *Why should COAL be placed ABOVE the wood ?*



A. Because otherwise, the *flame* from the wood would not rise *through the coal*, to heat it.

Q. *Why is a FIRE KINDLED at the LOWEST BAR of a grate?*

A. That the flame may *ascend through the fuel* to heat it. If the fire were kindled from the *top*, the flame would *not come in contact* with the fuel placed below.

Q. *Why does COAL make such EXCELLENT FUEL?*

A. Because it contains a large amount of *carbon* and *hydrogen gas*, in a compact and convenient form.

Q. *Why will cinders become RED HOT more quickly than COALS?*

A. Because they are sooner reduced to a state of combustion, as they are *more porous* and *less solid*.

Q. *Why will not IRON CINDERS burn?*

A. Because the *carbon* and *hydrogen* have been chiefly consumed, and only the incombustible part of the fuel remains.

Q. *Why are CINDERS lighter than COALS?*

A. Because they are full of little

holes or pores; from which gases, and other volatile parts, have been driven off by *previous combustion*.

Q. *Why will not STONES do for fuel, as well as COALS?*

A. Because they contain no elements suitable for combustion; and generally the substances of which they are composed are already *united to oxygen*.

Stones contain silix (i. e. silicon and oxygen); alumina (i. e. aluminum and oxygen); and lime (i. e. calcium and oxygen.) Some rocks contain sulphur, or a little carbon; in which case they burn feebly.

Q. *Why will not WET KINDLING light a fire?*

A. 1st—Because the moisture of the wet kindling prevents the *oxygen of the air from getting to the fuel*; and

2ndly—The heat of the fire is perpetually *drawn off*, by the conversion of *water into steam*.

Q. *Why does DRY wood burn BETTER than GREEN?*

A. 1st—Because none of its heat is *carried away* by the conversion of *water into steam*; and

2ndly—The pores of dry wood (being *filled with air*) supply the fire with oxygen.

Q. *Why does SALT CRACKLE, when thrown into a FIRE?*

A. Salt contains *water*. The *crackling* of burning salt is owing to the bursting of the crystals, when the water is converted into steam.

Q. *Why will not wood or paper burn if steeped in a solution of POTASH, phosphate of LIME, or AMMONIA (hartshorn)?*

A. Because any "al'kali," (such as potash) will *arrest the hydrogen* which escapes from the fuel, and prevent its combination with the *oxygen of air*.

Q. *What is an al'kali?*

A. A substance which will neutralize an acid.

Soda, potash, and ammonia, are all alkalis. The presence of an alkali may be detected thus:—Vegetable *blues* will be turned *green* by it; and turmeric paper will be turned *brown* by it.

Q. *Why does a JET of FLAME sometimes burst into the room through the BARS OF A STOVE?*

A. Because the iron bars conduct heat to the *interior of some lump of coal*; and its volatile gas (bursting through the weakest part) is kindled by the glowing coals over which it passes.

Q. *Does the JET of GAS ever escape unburnt?*

A. Yes. If the gas passes at once into the air, or over coals not sufficiently heated to ignite it.

Q. *Why does a BLUISH FLAME sometimes flicker on the surface of hot cinders?*

A. Because the gas from the hot coals at the *bottom of the grate*, mixing with the *carbon of the coals* above, produces an inflammable gas (called carbonic oxide), which burns with a blue flame.

Q. *Why is the FLAME of a fire or candle YELLOW?*

A. The flame of a fire or candle is due to a gas called carburetted hydrogen, which burns with a *yellow* flame.

Carburetted hydrogen is a compound of carbon and hydrogen. Pure hydrogen gas burns with a pale blue flame, and has very little illuminating power.

Q. *What is LIGHT?*

A.. Rapid *undulations* of a fluid called *ether*, striking upon the nerve of the eye.

Q. *How does COMBUSTION make these undulations of LIGHT?*

A. The atoms of matter (set in motion by heat) *striking against this ether*, produce *undulations* in it; as a

stone thrown upon water, produces undulations on the surface.

Q. *How can* UNDULATIONS *of ether produce perception of* LIGHT?

A. As *sound* is produced by *undulations of air* striking on the *ear*: so the *perception of light* is produced by undulations of *ether* striking on the *eye*.

Q. *What is the* LUMINOUS ETHER?

A. A very subtle fluid, which pervades all space, and surrounds *everything we see*.

N. B. This theory of LIGHT is not altogether satisfactory; but has been retained, as the best hitherto projected.

Q. *Does* HEAT ALWAYS *produce* LIGHT?

A. No: many substances, *particularly metals*, may be greatly heated without producing light.

Q. *Why is a* YELLOW FLAME *brighter than a* RED-HOT COAL?

A. Because *yellow rays* produce the greatest amount of *light*, though *red rays* produce the greatest amount of *heat*.

Q. *Why is the* LIGHT *of a fire* MORE INTENSE *sometimes, than it is at others?*

A. The *intensity* of fire-light depends upon the *whiteness* to which the carbon

is reduced by combustion. If carbon be *white hot*, its *combustion is perfect*, and the light intense; if not, the light is obscured by *smoke*.

Q. *Why will not CINDERS BLAZE, as well as FRESH coals?*

A. The *flame* of coals is caused by the burning of *carburetted hydrogen gas*. As soon as this gas has been consumed, the hot cinders produce only a gas, called carbonic acid, which is not combustible.

Q. *Where does the carburetted hydrogen gas of a blazing fire come from?*

A. From the fuel which is *composed* of carbon and hydrogen; these elements separate from each other during the process of combustion, and form into *new compounds*. (See p. 35.)

Fuel which will not blaze (as coke, cinders, charcoal, &c.) is devoid of hydrogen gas. Yet if sulphur be present, in any fuel, it will blaze to some extent.

• Q. *Why do coals burn out faster on a FROSTY NIGHT, than upon any other?*

A. 1st—Because air *condensed* by the cold contains more *oxygen* than the same quantity of warmer air; and

2ndly—Air condensed by the cold is *heavier*; in consequence of which, it falls more quickly on the fire, to supply the place of hot ascending air.

Q. *Why does a FIRE burn CLEARER on a FROSTY night?*

A. Because the volatile gases are more quickly consumed; and the solid carbon is *plentifully supplied with oxygen* from the air, to make it burn brightly and intensely.

Q. *Why does a FIRE burn more intensely in WINTER than in SUMMER?*

A. Because the air is *colder* in winter, than it is in summer.

Q. *Why does the COLDNESS of the air increase the HEAT of a fire?*

A. 1st—Because air condensed by the cold supplies more *oxygen*, than a similar volume of warmer air: and

2ndly—Condensed air, being *heavy*, falls more rapidly into the place of the hot ascending air, to supply the fire with nourishment.

Q. *Why does the SUN, shining on a FIRE, make it DULL, and often put it out?*

A. 1st—Because the air (being

rarefied by the sunshine) *flows more slowly to the fire*; and

2ndly—The chemical action of the sun's rays is detrimental to combustion.

The sun's rays are composed of three parts; lighting, heating, and actinic or chemical rays. The two latter interfere with the process of combustion.

Q. *Why does air flow to the fire more TARDILY for being RAREFIED?*

A. Because the greater the *contrast* (between the *external air*, and that which has been *heated by the fire*) the more *rapid* will be the current of air towards that fire.

Q. *Why does rarefied air afford LESS NOURISHMENT to fire than cold air?*

A. Because rarefied air contains less *oxygen*, than the same bulk of condensed air.

Inasmuch as the same quantity of oxygen is diffused through a larger space.

Q. *Why does a FIRE burn more fiercely in the OPEN AIR?*

A. 1st—Because the *air out-of-doors* is more *dense*, than the air in-doors; and

2ndly—It has freer *access* to the fire.

Q. *Why is the air out-of-doors more DENSE, than that in-doors?*

A. Because it has freer circulation;



and, as soon as any portion has been *rarefied*, it instantly escapes, and is supplied by *colder currents*.

Q. *Why does not a FIRE burn so freely in a THAW, as in a FROST ?*

A. Because the air is laden with *vapour*; in consequence of which, it both *moves too slowly*, and is too much *rarefied*, to nourish the fire.

Q. *Why does a FIRE burn very fiercely in WINDY weather ?*

A. Because *the air is rapidly changed*, and affords plentiful nourishment to the fire.

Q. *Why does a pair of BELLOWS get a fire up ?*

A. Because *it drives the air more rapidly to the fire*; and the plentiful supply of oxygen soon makes it burn intensely.

Clarke's Patent Blower is to be preferred, because it produces a continuous blast.

Q. *Why is the flame of a CANDLE EXTINGUISHED, when blown by the breath; and not made more intense, like a fire ?*

A. Because the flame of a candle is confined to a *very small wick*, from which it is *severed* by the breath; and (being unsupported) *must go out*.

Q. *Why is a SMOULDERING WICK sometimes RE-KINDLED by blowing it ?*

A. . Because air is carried to it by the breath with *great rapidity* ; and the oxygen of the air kindles the red-hot wick, as it would kindle charred wood.

Q. *Why is not the red-hot wick kindled by the air AROUND it, without BLOWING ?*

A. Because oxygen is not supplied with sufficient freedom, unless air be *blown* to the wick.

Q. *When is this experiment most likely to succeed ?*

A. In *frosty* weather ; because the air contains more oxygen, when it is *condensed by the cold*.

Q. *Why does a POKER, LAID ACROSS a dull FIRE, revive it ?*

A. For two reasons : 1st—Because the *poker concentrates the heat*, and throws it on the fuel : and

2ndly—Air is directed between the poker and the coals, and a slight draught created.

Q. *Why are the grates of modern STOVES fixed near the FLOOR of a room ?*

A. That the air *on the lower part of the room* may be heated by the fire.

Q. *Is not the air of the lower part of a room heated equally well, when the grates are fixed higher up?*

A. No; the heat of a fire has a very little effect upon the air *below the level of the grate*; and, therefore, every grate should be as *near to the floor* as possible.

Q. *Our FEET are very frequently COLD, when we sit close by a good fire. Explain the reason of this.*

A. Because *cold air* rushes through the crevices of the doors and windows *along the bottom of the room*, to supply the place of that heated by the fire which ascends with the smoke; and these currents of cold air, *rushing constantly over our feet*, deprive them of warmth.

Q. *If a piece of PAPER be laid FLAT on a clear fire, it will NOT BLAZE, but CHAR. Why so?*

A. Because the carbon of a clear fire, being sufficiently hot to unite with the oxygen of the air, *produces carbonic acid gas*, which soon envelopes the paper laid

flat upon the cinders : but carbonic acid gas will neither *blaze*, nor allow combustible matter surrounded by it to do so.

Q. *If you BLOW the paper, or open the door suddenly, it will BLAZE immediately. Why so ?*

A. Because *the carbonic acid is dissipated*, and the paper fanned into flame.

Q. *Why does WATER EXTINGUISH a FIRE ?*

A. 1st—Because it *forms a coating* over the fuel, which keeps it from the air : and

2ndly—The conversion of *water into steam*, draws off the *heat* of the burning fuel.

Q. *A LITTLE WATER makes a fire FIERCER, while a LARGER quantity of water puts it OUT. Explain how this is.*

A. A *little* water is readily converted into *steam*, which increases the heat of a fire ; but water plentifully supplied is not converted into steam, and stops combustion.

Q. *When the COALS upon a fire are small and DUSTY ; why are they sometimes sprinkled with water ?*

A. Because water makes the mass more solid, and the steam assists to heat the coals into perfect combustion.

Q. *When a house is on fire, is too LITTLE water worse than NONE ?*

A. Certainly. Unless water be supplied so plentifully as to *quench the fire*, it will increase its *intensity*.

Q. *When will water EXTINGUISH FIRE ?*

A. When the supply is so rapid and abundant, that the fire cannot convert it into steam.

Q. *Does not a very LITTLE water SLACKEN the heat of fire ?*

A. Yes, till it is converted into steam ; it then increases the *intensity* of fire.

Q. *Why does the WICK of a candle (when the flame has been blown out) very readily CATCH FIRE ?*

A. Because it is already *hot*, and a very little *extra* heat will throw it into flame.

Q. *Why does the EXTRA heat revive the flame ?*

A. Because it again liberates the *hydrogen* of the tallow, and ignites it.

Q. *Cannot WOOD be made to BLAZE without actual contact with fire ?*

A. Yes ; if a piece of wood be held near a fire for a little time, it will blaze, even though it does not *touch* it.

Q. *Why will* WOOD BLAZE, *even if it does not touch fire?*

A. Because the heat of fire *drives out the hydrogen gas* of the wood; which gas is inflamed by the fire.

Q. *Why will a* NEIGHBOUR'S. HOUSE *sometimes CATCH FIRE, though no flame of the burning house ever touches it?*

A. Because the heat of the burning house sets at liberty *the hydrogen gas* of the neighbouring wood-work; and this gas is ignited by the flames or red-hot bricks of the house on fire.

The gas referred to, in both these answers, is not *pure*, but *impure* (or carburetted) hydrogen.

Q. *What is* COKE?

A. Coal freed from its volatile gases, by the action of artificial heat.

Q. *Why do* ARNOTT'S STOVE *sometimes SMELL very strongly of* SULPHUR?

A. Because coke contains sulphur; and whenever the draught is not rapid enough *to drive the sulphur up the flue*, it is emitted into the room.

Q. *What is meant by* SPONTANEOUS COMBUSTION?

A. Combustion produced without the application of *flame*.

Q. *Give an example of spontaneous combustion.*

A. Coals stowed in the hold of a vessel, and goods packed in a warehouse, will often catch fire of *themselves*,—especially such goods as cotton, flax, hemp, rags, &c.

Q. *Why do such goods sometimes CATCH FIRE of themselves?*

A. Because they are piled together in *large masses* in a *damp* state or place.

Q. *Why does this produce spontaneous combustion?*

A. Because the damp produces *decay*; and the great heat of the piled-up mass makes the decaying goods *ferment*.

Q. *How does this FERMENTATION produce COMBUSTION?*

A. During fermentation, great heat is produced by chemical action,—a slow combustion ensues,—till at length the *whole pile* bursts into *flame*.

Q. *Why is the HEAT of a LARGE MASS of goods GREATER than that of a smaller quantity?*

A. Because the heat produced cannot

escape through the massive pile; it therefore accumulates, and raises the temperature of the heap.

Q. *Why do HAY-STACKS sometimes CATCH FIRE of themselves?*

A. Either because the hay was got up *damp*; or else because *rain* has penetrated the stack.

Q. *Why will a HAY-STACK CATCH FIRE, if the hay be damp?*

A. Because damp hay soon *decays*, and undergoes a *state of fermentation*, during which great heat is produced, and the stack catches *fire*.

Q. *Is the HAY in a stack injured by "HEATING," if it does not CATCH FIRE?*

A. Yes; it is frequently *charred* and turned black; which renders it unfit for use.

Q. *If a hay-stack is found to be "heating," what can be done to prevent its catching fire, or spoiling the HAY?*

A. It may be taken down and re-formed into a stack after it has been further dried: or a chimney may be formed in the middle of the stack to carry off the heat.



## CHAPTER IV.

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SMOKE.

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Q. *Why does smoke ASCEND a chimney?*

A. Because the air of the room passing over the fire becomes lighter for being *heated*; and (being thus made *lighter*) ascends the chimney, carrying the smoke with it.

Q. *Why does lighter heated air ascend in a chimney?*

A. Because the heavier cold air in the room presses it up.

Q. *What determines the rapidity or strength of the draught in a chimney?*

A. The difference of weight between the *cold air* which supplies the fire, and the *hot air* in the chimney flue.

Q. *Why is the draught of a short flue more slack than that of a long one?*

A. Because the *shorter* the flue, the *less difference* of weight is there between

the ascending current, and the air which presses it up the chimney.

If chimneys are too high, in comparison *with the size of the fire*, the ascending air gets *cold* before it reaches the top: and the draught is injured.

Q. *Why do SMOKE and steam assume a wreathy or curly form?*

A. Because they are pushed round and round by ascending and descending currents of air.

Q. *What are BLACKS?*

A. Smoke condensed into flakes, which fall to the earth by their own weight.

Q. *Why are there no blacks thrown from the funnel of a railway engine?*

A. Because *condensed steam* alone escapes from the railway engine, which is *dissolved* by the air.

The fuel burnt in the furnace is so perfectly consumed, owing to the sharpness of the draught, that very little deposit of soot can take place.

The black deposit, which sometimes annoys the railway traveller, arises from water thrown through the chimney of the locomotive, made dirty in its passage.

Q. *Why does a "FURNACE-FIRE" DRAW up more fiercely, than an OPEN stove?*

A. Because the air, which supplies the fire, must pass *through the*

*furnace* ; and, as it becomes exceedingly heated, rushes up the chimney with great violence.

Q. *What produces the ROARING noise made by a FURNACE fire ?*

A. Air rushing rapidly through the crevices of the *iron door*, and up the *chimney flue*.

Q. *Why is the ROAR less if the furnace DOOR be thrown OPEN ?*

A. Because *fresh air* gets access to the fire *more easily* ; and, as the air is not so intensely heated, its motion is not so violent.

Q. *Why do some CHIMNEYS SMOKE ?*

A. Because fresh air is not admitted into the room *so fast as it is consumed by the fire* ; in consequence of which, a current of air *passes down the chimney* to supply the deficiency, driving the smoke along with it.

Q. *What things would prevent air from being supplied as fast as it is consumed by the fire ?*

A. Leather and curtains round the doors ; sand-bags at the threshold and

on the window-frames; and other contrivances to keep out the draught.

Q. *Why will the air come down the CHIMNEY?*

A. Because it can get to the fire in no *other* way, if the doors and windows are all made *air-tight*.

Q. *What is the best REMEDY in such a case?*

A. The *speediest* remedy is to open the door or window; but by far the *best* remedy is to carry a small tube from the hearth into the external air.

Q. *Why is that the BEST remedy?*

A. Because the fire will be plentifully supplied with air by the tube: the doors and windows may all remain *air-tight*; and we may enjoy a warm fireside, without the inconvenience of draughts and cold feet.

Q. *Why is a CHIMNEY raised so high above the ROOF?*

A. That it may not smoke; as all funnels do, which are too short.

Q. *What is meant by the FUNNEL or FLUE of a chimney?*

A. That part of a chimney through which the *smoke passes*.

Q. *Why does a CHIMNEY SMOKE, if the funnel be very short?*

A. Because the draught of a short flue is *too slack* to carry the smoke up the chimney.

Q. *On what does the INTENSITY of fire depend?*

A. The *intensity* of fire is always in proportion to the *quantity of oxygen* with which it is supplied.

Q. *Does the DRAUGHT of a chimney depend on the SPEED of the SMOKE through the flue?*

A. Yes. The more quickly *hot air* flies up a chimney, the more quickly *cold air* will rush towards the fire to supply its place; and, therefore, the *longer the flue*, the *greater the draught*.

Q. *Why are the CHIMNEYS of MANUFACTORIES made so very LONG?*

A. To increase the intensity of the fire.

Another reason of this arrangement is to prevent the annoyance caused by the smoke and unwholesome gases, when they escape too near to inhabited dwellings.

Q. *Why is the INTENSITY of a fire increased by LENGTHENING a FLUE?*

A. Because the draught being greater, more *fuel* is consumed in the same time;

and, of course, the *intensity* of the heat is proportionally greater.

Q. *If a SHORT CHIMNEY cannot be lengthened, what is the best REMEDY to prevent smoking?*

A. To *contract the opening of the chimney* contiguous to the stove.

Q. *Why will a SMALLER OPENING above the stove, PREVENT a chimney's SMOKING?*

A. Because the air will be compelled to pass *nearer the fire*; and (being more *heated*) will rise through the chimney more rapidly: This *increase of heat* will, therefore, compensate for the *shortness of the flue*.

Q. *Why will a ROOM SMOKE, if there be TWO FIRES in it?*

A. Because the *fiercer* fire will exhaust the most air; and may draw from the *smaller* one, to supply its demand.

This inconvenience does not arise in large rooms, with fire properly adjusted.

• Q. *Why will a chimney SMOKE, if there be a FIRE in TWO ROOMS communicating with each other?*

A. Because (whenever the *door* between the two rooms is *opened*) air will rush from the chimney of the *inferior*

fire to supply the *other* ; and *both* rooms will be filled with smoke.

Q. *What is the best REMEDY in this case ?*

A. To carry a tube from the hearth of each stove into the external air ; and then *each* fire will be so well supplied, that neither will need to borrow from the other.

Q. *Why do VESTRY CHIMNEYS so often smoke ?*

A. Because the wind (striking against the steeple) *is reflected back* ; and, rushing down the vestry chimney, forces the smoke *into the room*.

Q. *WHAT WINDS make vestry chimneys smoke ?*

A. Those from the north-east or south-east ; according to the position of the vestry.

Q. *Why will EAST winds make VESTRIES SMOKE, more than west winds ?*

A. Because *east winds strike against the steeple*, and *bound back again* to the vestry chimney : but *west winds* cannot rebound over the roof of a church.

N. B. The *steeple* of a church is always due *west*, and the *other* end of the church due *east* ; if, therefore, a *west* wind were to rebound, it would rebound to the *west*, (or *away from the church*), and not *towards* it.

Q. *Why does a HOUSE in a VALLEY very often SMOKE?*

A. Because the wind (striking against the surrounding hills) *bounds back again upon the chimney*, and destroys its draught.

Q. *What is the common REMEDY in both these cases?*

A. To fix a *cowl* on the chimney-top, to turn like a weather-cock, and present its back to the wind.

Q. *Why will not a COWL always PREVENT a chimney SMOKING?*

A. Because a *strong* wind will keep the *opening* of the cowl *towards the steeple or hill*; and then the reflected wind will blow *into the cowl*, and *down the chimney*.

Q. *As a cowl is such a poor remedy, what OTHER can be suggested?*

A. If the chimney-flue can be carried *higher* than the steeple or hills, no wind can enter the flue.

Q. *If a chimney flue be carried up HIGHER than the steeple or hill, why cannot the wind enter it?*

A. Because the reflected wind would strike against the *sides* of the chimney-flue, and not pass over its *opening* at all.



Q. *In what OTHER cases will a CHIMNEY SMOKE ?*

A. If the door and stove are both placed on *the same side of a room*, the chimney will often smoke.

Q. *Why will a CHIMNEY SMOKE, if the DOOR and STOVE are both on the SAME SIDE ?*

A. Because (whenever the door is opened) a current of air will *blow obliquely into the chimney-place*, and drive the smoke into the room.

Q. *What REMEDY can be applied to this evil ?*

A. The door must be set *opposite* to the chimney-place, or nearly so ; and then the draught from the door *will blow the smoke up the chimney*, and not into the room.

Q. *Why will a CHIMNEY SMOKE if it NEEDS SWEEPING ?*

A. Because loose soot obstructs the free passage of the smoke, *checks the current*, and prevents the draught. .

Q. *Why will a CHIMNEY SMOKE, if it be OUT OF REPAIR ?*

A. 1st—Because the *loose mortar and bricks* obstruct the smoke : and

2ndly—*Cold air* (oozing through the

chinks) *chills the air in the chimney*, and prevents its ascent.

Q. *Why will an ARNOTT'S STOVE SMOKE, if the joints of the flue do not fit air-tight?*

A. Because *cold air* (oozing through the joints) *chills the air in the flue*, and prevents its ascent.

Q. *Why does an old fashioned FARM CHIMNEY-PLACE generally smoke?*

A. Because the opening is so *very large*, that much of the air which goes up the chimney, *has never passed near the fire*; and this *cold air* (mixing with the hot) so *reduces its temperature*, that it ascends very slowly, and the draught is destroyed.

Q. *Why does a chimney smoke, if the DRAUGHT be SLACK?*

A. Because the current of air up the chimney is not powerful enough to *buoy up the smoke* through the flue.

Q. *If the opening of a chimney be TOO LARGE, what REMEDY can be applied?*

A. The chimney-place must be contracted. •

Q. *Why will CONTRACTING the chimney-place PREVENT its SMOKING ?*

A. Because the air will then pass *nearer the fire* ; and (being *more heated*) fly faster up the chimney.

Q. *Why do almost all CHIMNEYS SMOKE in GUSTY weather ?*

A. Because the column of smoke is suddenly chilled by the wind, and (being unable to ascend) rushes back into the room.

Q. *What is the use of a CHIMNEY-POT ?*

A. To increase the draught, when the opening of a chimney is too *large*.

Q. *How does a CHIMNEY-POT INCREASE the DRAUGHT of a chimney ?*

A. 1st—By diminishing the aperture of the funnel, and thus preventing cold air from entering the chimney to chill the warm ascending air : and

2ndly—By lengthening the flue, and increasing the draught.

Q. *Why do TIN BLOWERS help to get a fire up ?*

A. Because they compel the air to

go *through* the fire, and not *over* it; in consequence of which, the fire is well supplied with oxygen, and the draught greatly increased.

Q. *Why does a BLOWER INCREASE the DRAUGHT?*

A. Because it compels the air to pass *through* the fire; and, being made much hotter, it ascends the chimney more rapidly.

Q. *Why is a fire better supplied with oxygen, while the blower hangs before it?*

A. Because the draught is increased; and the faster the *hot* air flies *up the chimney*, the faster will *cold* air rush *towards the fire*, to supply it with oxygen.

Q. *Why does a parlour often SMELL disagreeably of SOOT in SUMMER-TIME?*

A. . Because the air in the *chimney* (being *colder* than the air in the *parlour*) *descends into the room*, and leaves a disagreeable smell of soot behind.

Q. *Why are the CEILINGS of PUBLIC OFFICES generally BLACK and filthy?*

A. Because the heated air of the office

carries up the dust and fine soot; which is deposited on the ceiling.

Q. *Why are SOME parts of the ceiling BLACKER and more filthy than others?*

A. Because the ceiling, by the drying of the plaster, becomes uneven, and the currents of air which pass over it, deposit the dust or fine soot on the more prominent parts.

Q. *What is CHARCOAL?*

A. Wood which has been exposed to a red heat, till it has been deprived of all its gases and volatile parts.

Q. *Why is a CHARCOAL FIRE hotter than a wood fire?*

A. Because charcoal is nearly pure carbon, while wood contains other elements; and, as it is the *carbon* of fuel which produces the glowing heat of combustion, therefore, the purer the carbon, the more intense will the heat of a fire be.

Q. *Why does charcoal REMOVE the TAIN of meat?*

A. Because it absorbs all putrescent

effluvia, whether they arise from animal or vegetable matter.

Q. *Why is WATER PURIFIED by being filtered through charcoal?*

A. Because charcoal absorbs the *impurities* of water, and removes all disagreeable tastes and smells, whether they arise from animal or vegetable matter.

Q. *Why are water and wine casks CHARRED inside?*

A. Because *charring* the inside of a cask reduces it to a kind of *charcoal*; and charcoal (by absorbing animal and vegetable impurities) keeps the liquor sweet and good.

Q. *Why does a piece of BURNT BREAD make impure water more fit to drink?*

A. . Because the surface of the bread (which has been reduced to *charcoal* by being burnt) corrects the *impurities* of the water, and makes it palatable.

Q. *Why should TOAST and WATER, placed by the side of the sick, be made of BURNT bread?*

A. Because the charcoal surface of

burnt bread prevents the water from being affected by the impurities of a sick room.

Q. *Why are* TIMBERS, *which are to be exposed to damp,* CHARRED?

A. Because *charcoal undergoes no change* by exposure to air and water: in consequence of which timber will resist weather *much longer*, after it has been charred.

Q. *Why are* POSTS, *which are fixed in the ground,* CHARRED?

A. Because charred wood resists decay, which would otherwise affect the part underground, from the *moisture* of the earth.

Q. *What precaution is necessary in charring posts?*

A. To continue the "charring" beyond the part buried in the ground; lest the post should decay at the *base*, from rain and other moisture on the earth's surface.

The post should be charred to about one foot above the ground.

## CHAPTER V.

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LAMPS AND CANDLES.

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Q. *Of what are OIL, TALLOW, and WAX composed?*

A. Principally of carbon and hydrogen gas. The *solid* part is carbon, the *volatile* part is hydrogen gas.

Oxygen also, in small proportions, enters into the composition of some substances used for candles.

Q. *What is CARBON?*

A. A solid substance, generally of a black colour; well known under the forms of charcoal, lamp-black, coke, &c.

Q. *What is HYDROGEN GAS?*

A. One of the elements of water. It burns so readily, that it used to be called "inflammable air."\*

Common coal gas is a compound of carbon and hydrogen, called "carburetted hydrogen." See p. 293.

Q. *A CANDLE BURNS when lighted.—Explain how this is.*

A. The heat of the lighted wick decomposes the tallow or wax; and forms vapour of water, and carbonic acid gas.

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\* Directions for making hydrogen gas are given on p. 37.



Q. *How are vapour of water and carbonic acid gas formed from the burning tallow or wax of a candle?*

A. The *hydrogen* of the candle, combining with the *oxygen* of the air, forms *vapour of water*: and the *carbon* of the candle, combining with the *oxygen* of the air, forms *carbonic acid gas*.

Q. *WHERE is the tallow or wax of a candle decomposed?*

A. In the *wick*. The melted tallow, or wax, *rises up the wick* by capillary attraction, and is rapidly decomposed by the heat of the flame.

Q. *What is CAPILLARY ATTRACTION?*

A. The power which very minute tubes possess, of causing a liquid to rise in them above its level.

“Capillary,” from the Latin word, “capillaris” (*like a hair*); the tubes referred to are almost as fine and delicate as a hair.

Water ascends through a lump of sugar, or piece of sponge, by capillary attraction. N. B. The smaller a tube, the higher will a liquid be attracted in it.

Q. *Why is the FLAME of a candle HOT?*

A. Because it liberates *latent heat* from the air and tallow.

Q. *How is LATENT HEAT liberated by the flame of a candle?*

A. When the elements of the tallow combine with the *oxygen* of the air, latent heat is liberated by the chemical changes.

Q. *Why does the flame of a CANDLE produce LIGHT?*

A. Because the chemical changes made by combustion, excite *undulations of luminous ether*, which (striking the eye) produce light. (See p. 47.)

Q. *Describe the different parts of the FLAME of a common CANDLE.*

A. The flame consists of *three* cones: The *inner* or *hollow* cone, in which no combustion takes place;—the *intermediate* cone or *area* of partial combustion, in which the *hydrogen* is chiefly consumed;—and the *outer* cone or *area* of perfect combustion, in which the *carbon* is principally burned.

\*Q. *Why does the INSIDE of the flame appear HOLLOW?*

A. Because it is filled with *invisible vapour* raised from the candle by the heat of the wick; which cannot be burnt unless in contact with the air.

Q. *From which part of the flame is the greatest illuminating power derived?*

A. From the *intermediate cone*, in which the burning gas raises the particles of carbon to a *white heat*; upon which the illuminating power depends.

Q. *Why, for the most part, is only the hydrogen consumed in the intermediate cone?*

A. Because the *oxygen* of the air has a *greater affinity* for *hydrogen* than for *carbon*; and that which penetrates to this part of the flame, not being *sufficient* to combine with *both*, unites with *hydrogen* to form *water*.

Q. *Why is the MIDDLE CONE in a state of less perfect combustion than the outer?*

A. Because the *outer cone* prevents the *oxygen of the air* from getting freely to the middle of the flame; and without free access of oxygen, there cannot be complete combustion.

Q. *Why is the OUTER of less illuminating POWER than the INTERMEDIATE cone?*

A. Because the *incandescent carbon*, which passes to the *outer cone*, is immediately consumed by combining with the *oxygen of the air*, to form *carbonic acid gas*.

“Incandescent,” that is, heated to whiteness.

Q. *Why is the BOTTOM of the flame purple?*

A. Because it contains very little incandescent carbon, on which the illuminating power of a candle depends.

Q. *Why does the FLAME of a candle point UPWARDS?*

A. Because it *heats the surrounding air*, which (being hot) *rapidly ascends*, carrying the flame upwards at the same time.

Q. *Why is the FLAME of a candle POINTED at the top, like a cone?*

A. Because, as the cone of heated vapour rises, it is *consumed*; and its surface being *diminished*, a *pointed form* is given to the flame.

"Consumed," that is, converted into vapour of water and carbonic acid gas.

Q. *Why is the FLAME of a candle BLOWN OUT by a puff of breath?*

A. Because it is *severed from the wick*, and goes out for want of support.

Q. *Why does the FLAME of a candle make a glass (which is held over it) DAMP?*

A. Because a "watery vapour" is made, by the combination of the *hydrogen of the tallow* with the *oxygen of the air*;

which is condensed by the *cold glass*, held above the flame.

Water is composed of oxygen and hydrogen gases, chemically united.

Q. *Why does the hand, held ABOVE a candle, suffer more from heat, than when it is placed BELOW the flame, or on ONE SIDE of it ?*

A. Because the ascending *heated air* comes in contact with the hand placed *above* the flame; but when the hand is placed *below* the flame or on *one side*, it only feels heat from *radiation*.

“Radiation :” i. e. emission of rays. The candle-flame throws out rays of light and heat in all directions; but when the hand is held *above* the flame, it not only feels the heat of the *rays*, but also of the ascending current of *hot air*.

Q. *Why is a RUSH-LIGHT extinguished more quickly, than a cotton-wick candle ?*

A. Because a hard rush imbibes the melted fat or wax much more slowly than porous cotton; as it imbibes less fat, it supplies a smaller volume of *combustible gases*; the flame is, therefore, smaller, and more easily extinguished.

Q. *Why is it more difficult to blow out a COTTON wick, than a rush-light ?*

A. Because porous cotton imbibes the melted fat, or wax, much more quickly,

than hard rush: as it imbibes more fat, it supplies the flame with a larger volume of *combustible gases*; and, of course, the light is with more difficulty extinguished.

Q. *Why is a GAS FLAME more easily extinguished, when the jet is very slightly turned on, than when it is in full stream?*

A. Because there is less volume of combustible gases in the small flame, than in the full blaze.

Q. *Why does an EXTINGUISHER put a candle out?*

A. Because the air in the extinguisher is soon *exhausted of its oxygen* by the flame: and when there is *no oxygen*, flame goes out.

Q. *Why does not a candle set fire to a PIECE of PAPER twisted into an extinguisher, and used as such?*

A. 1st—Because the flame very soon *exhausts the oxygen* contained in the paper extinguisher: and

2ndly—The flame invests the *inside of the paper extinguisher* with *carbonic acid gas*, which prevents it from blazing.

Q. *Why is a LONG WICK never upright ?*

A. Because it is bent by its own weight.

Q. *A LONG WICK is covered with an EFFLORESCENCE at the top.—What does this arise from ?*

A. This knotty or flowery appearance arises from an accumulation of *charred particles* of cotton, which have not been completely burnt, because the oxygen of the atmosphere has been kept from them by the outer cone of the flame.

Q. *Why is not the END of a long wick burnt off, as it hangs over the flame ?*

A. Because the *length* and *thickness* of the unburnt wick so *diminishes the flame* and *checks combustion*, that there is not heat enough to *consume* the charred particles.

Q. *Why do the wicks of Palmer's candles never require snuffing ?*

A. Because the wick is divided into two or more parts, which, with the assistance of a *fine wire* twisted with the cotton, spread and project *beyond the flame* ; where they are readily consumed.

Immediately the wick reaches the *outer cone* of the flame it is consumed, because the supply of oxygen is very plentiful there.

Q. *Why do common candles require to be snuffed?*

A. Because the wick is surrounded by the *outer cone* of the flame, which prevents a sufficient *supply of oxygen* to cause *complete combustion*.

Q. *Why do wax and composite candles never require snuffing?*

A. Because the wick is so platted as to bend into the outer cone, where it is completely consumed.

Q. *Why is this plan not adopted in making tallow candles?*

A. Because the bending of the wick, which causes part of the flame to project, would melt the tallow on one side too quickly, causing the candle to "*gutter*."

Tallow melts at a lower temperature than wax or stearine; which prevents the employment of this plan for consuming the wick.

.Q. *What is the SMOKE of a CANDLE?*

A. Solid particles of carbon, separated from the wick and tallow, but not consumed.

Q. *Why are SOME particles consumed, and not OTHERS?*



A. Because the outer surface of the flame *prevents the access of air to the interior parts*, whence much of the carbon passes off in smoke.

*The combustion of the carbon depends upon its combining with the oxygen of the air.*

Q. *Why do LAMPS SMOKE?*

A. Either because the *wick is cut unevenly*, or else because it is *turned up too high*.

Q. *Why does a LAMP SMOKE, when the WICK is cut UNEVENLY?*

A. Because the points of the *jagged edge* project into the flame, where the supply of oxygen is not sufficient to consume all the carbon.

Q. *Why does a LAMP SMOKE, when the WICK is turned up too HIGH?*

A. Because more carbon is separated from the wick, than can be *consumed by the flame*.

Q. *Why do not "ARGAND BURNERS" smoke?*

A. Because a current of air passes through the *middle of the flame*; in consequence of which, the carbon of the *interior* is consumed, as well as that in the *outer coating of the flame*.

Q. *Why does a LAMP-GLASS DIMINISH the SMOKE of a lamp?*

A. 1st—Because it increases the supply of *oxygen* to the flame, by producing a draught; and

2ndly—It *concentrates* and *reflects* the *heat* of the flame; in consequence of which, the combustion of the carbon is more *perfect*, and very little escapes unconsumed.

## CHAPTER VI.

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### ANIMAL HEAT.

Q. *What is the cause of ANIMAL HEAT?*

A. Animal heat is produced by the combustion of *hydrogen* and *carbon* in the capillary vessels.

Q. *What are CAPILLARY VESSELS?*

A. Vessels as small as hairs running all over the body; they are called capillary

from the Latin word "*capilla'ris* (*like a hair.*)

Q. *Do these* CAPILLARY VESSELS *run all over the human body?*

A. Yes. Whenever *blood flows from a wound*, some blood-vessel must be divided; and, as you can bring blood from any part of the body by a very slight wound, these little vessels must run through every part of the human frame.

Q. *How do* HYDROGEN *gas and* CARBON *get into these very minute vessels?*

A. The food we eat is *converted into blood*; and blood contains both *hydrogen and carbon*.

Q. *How does* COMBUSTION *take place in the capillary vessels?*

A. The *carbon of the blood* combines with the *oxygen of the air we breathe*, and forms *carbonic acid gas*.

Q. *What becomes of this* CARBONIC ACID GAS, *formed in the human blood?*

A. The lungs throw off almost all of it into the air, by the act of expiration.

Q. *What* GAS *is generated in a common* FIRE *by* COMBUSTION?

A. *Carbonic acid gas*,—formed by the union of the carbon of fuel with the oxygen of air.

Q. What GAS is generated by a lighted CANDLE or LAMP?

A. *Carbonic acid gas*,—formed by the union of the carbon of oil or tallow with the oxygen of air.

Q. What is the cause of HEAT in the ANIMAL system?

A. It is produced by a species of slow combustion in the body.

Q. Does the HEAT of the HUMAN BODY arise from the SAME CAUSE as the heat of FIRE?

A. Yes, it does. The carbon of the blood combines with the oxygen of the air inhaled, and produces carbonic acid gas.

Q. If animal heat is produced by COMBUSTION, why does not the human body BURN UP like a coal or candle?

A. It actually does so. Every muscle, nerve, and organ of the body, wastes away like a burning lamp; and (being reduced to air and ashes) is rejected from the system as useless.

Q. *If every bone, muscle, nerve, and organ, is thus consumed by combustion, why is not the body entirely CONSUMED?*

A. It would be so, unless the parts destroyed *were perpetually renewed*: but as a lamp will not go out, so long as it is *supplied with fresh oil*,—neither will the body be consumed, so long as it is *supplied with sufficient food*.

Q. *What is the principal difference between the combustion of a FIRE or LAMP, and that of the HUMAN BODY?*

A. In the human body, the combustion is affected at a much *lower temperature*; and carried on more *slowly*, than in a lamp or fire.

The fire of one's body is not hotter than from 90 to 104 degrees. This heat is, nevertheless, sufficient to burn some things. For example, a little piece of phosphorus will ignite, if it gets by accident under the nail.

Q. *How is it, that carbon can be made to burn at so LOW a temperature in the human body?*

A. Because the carbon in the blood is reduced to very *minute particles*, ready to undergo a rapid change immediately oxygen is supplied.

Q. *When a man is STARVED, what parts of the body go first?*

A. First the *fat*, because it is the most combustible; afterwards the *muscles*; and then the man dies, like a *lamp which is burnt out*.

Q. *Why does WANT of sufficient NOURISHMENT often produce MADNESS?*

A. Because while the *fat and muscles* of the body are consuming by animal combustion, the brain also is attacked; and disease is produced in it before it is finally destroyed.

Q. *Why does a man SHRINK, when STARVED?*

A. Because the capillary fires feed upon the human *body*, when they are not supplied with food-fuel. A starved man shrinks *just as a fire does*, when it is not supplied with fuel.

Q. *What is the FUEL of the BODY?*

A. *Food* is the fuel of the body. The *carbon of the food*, combining with the *oxygen of the air*, evolves heat, in the same way that a fire or candle does.

Q. *Why is EVERY part of the BODY WARM?*

A. Because the capillary vessels run through every part of the human body

and the combustion of blood *takes place in the capillary vessels.* (See p. 86.)

Q. *Why does RUNNING make us warm?*

A. Because we inhale more air, and cause the blood to pass more rapidly through the lungs. *Running* acts upon blood in the capillary vessels, as a pair of bellows on a common fire.

Q. *Why does inhaling air RAPIDLY make the body feel WARM?*

A. Because *more oxygen* is introduced into the body. In consequence of which, the combustion of the blood is *more rapid*,—the blood itself *more heated*,—and every part of the body is made warmer.

Q. *Why does HARD WORK produce HUNGER?*

A. Because it produces *quicker respiration*; by which means, a *larger amount of oxygen* is introduced into the lungs, and the *capillary combustion* increased. Hunger is the *notice* (given by our body) to remind us, that our *food-fuel* must be replenished.

Q. *Why do want of exercise and too abundant feeding make men fat or ill?*

A. Because more *hydrogen* and *carbon* are taken into the *blood* than can be consumed by the *respiration*; these, therefore, either turn to fat, or cause some *disturbance* in the *system*, which is called *disease*.

Q. *Why do SINGING and READING ALOUD make us feel hungry?*

A. Because they *increase respiration*; and, as more *oxygen* is introduced into the lungs, our *food-fuel* is more rapidly consumed.

Q. *Why do we feel less HUNGRY in the night, than in the day?*

A. Because we breathe *more slowly during sleep*; therefore, less *oxygen* is introduced into the lungs, to consume our *food-fuel*.

Q. *Why do we need WARMER CLOTHING by NIGHT, than by DAY?*

A. 1st—Because the *night* is generally *colder*, than the day: and

2ndly—Because we breathe *more slowly*: In consequence of which, animal combustion is retarded, and our bodies are *colder*.



Q. *Why do we PERSPIRE, when very hot ?*

A. Because the pores of the skin are thrown open to let some of the fluids of the blood escape.

Q. *Why do persons feel LAZY and averse to exercise, when they are HALF-STARVED or ILL-FED ?*

A. Because desire for muscular action ceases, when the body is not supplied with nutritious food.

Q. *Why have persons, who follow HARD OUT-OF DOORS OCCUPATIONS, more APPETITE than those who are engaged in SEDENTARY pursuits ?*

A. Because hard bodily labour in the open air *causes much oxygen* to be conveyed into the *lungs by inspiration*; the combustion of the food is carried on quickly; *animal heat increased*; and need for nutritious food more quickly indicated by *craving hunger*.

Q. *Why have persons, who follow SEDENTARY PURSUITS less APPETITE, than ploughmen and masons ?*

A. 1st—Because the air they inhale is *less pure*, being deprived of some of its oxygen: and

2ndly—Their respiration is neither *so quick, nor so strong* ; and, therefore, the combustion of their food is carried on more slowly.

Q. *Why do we like strong MEAT, and GREASY food, when the weather is very COLD ?*

A. Because strong meat and grease contain large portions of *carbon* and *hydrogen* ; which produce a larger amount of heat (when burned in the blood) than any other kind of food.

Q. *Why do persons EAT MORE food in cold weather, than in hot ?*

A. Because the body requires more fuel in *cold weather*, to keep up the *same amount of animal heat* ; and as we put more *coals* on a fire on a cold day, to keep our *room* warm ; so we eat more *food* on a cold day, to keep our *body* warm.

Q. *Why does cold produce HUNGER ?*

A. 1st—Because the air contains more *oxygen* in cold weather ; and, therefore, fires burn *more fiercely*, and *animal combustion is more rapid* : and

2ndly—As we are more *active* in cold weather, our increased respiration acts

*a pair of bellows on the capillary combustion.*

Q. *Why does rapid DIGESTION produce a craving APPETITE?*

A. This is a wise provision to *keep our bodies in health*; hunger gives notice that the *capillary fires need replenishing*, in order that the *body itself* may not be consumed.

Q. *Why do we feel a desire for ACTIVITY in cold weather?*

A. 1st—Because activity increases the warmth of our body, *by fanning the combustion of the blood*: and

2ndly—The *strong food* we eat creates a desire for muscular exertion.

Q. *Why are the Esquimaux so passionately fond of TRAIN OIL and WHALE BLUBBER?*

A. Because oil and blubber contain large quantities of *carbon and hydrogen*, which are exceedingly combustible; and the heat of their bodies is increased by the *greasy nature of their food*.

Q. *Why do we feel a DISLIKE to strong meat and greasy food in very HOT weather?*

A. Because strong meat and grease contain so much *carbon and hydrogen*, that they would make us *intensely hot* : we, therefore, instinctively refuse them in hot weather.

Q. *Why do we like* FRUITS *and* VEGETABLES *most in hot weather ?*

A. Because they contain *less hydrogen and carbon* than meat ; and, therefore, produce not only *less blood*, but blood of a *less combustible nature*.

Q. *Why is our blood of a less COMBUSTIBLE nature, if we live chiefly upon* FRUITS *and* VEGETABLES ?

A. Because fruits and vegetables supply the blood with a very large amount of *water* ; which is not combustible, like the *carbon and hydrogen* of strong meat.

Q. *How do* FRUITS *and* VEGETABLES *cool the* BLOOD ?

A. 1st—They diminish the amount of *carbon and hydrogen* in the blood, which are the chief causes of animal heat: and

2ndly—They supply the blood with a

large amount of *water*, which exudes *through the skin*, and leaves the body cool.

Q. *Why do we feel LAZY and averse to activity in very HOT weather?*

A. 1st—Because muscular activity increases the heat of our body, by *quickenning respiration* : and

2ndly—The food we eat in hot weather (not being *greasy*) naturally abates our desire for bodily activity.

Q. *Why do the inhabitants of TROPICAL countries live chiefly upon RICE and FRUIT?*

A. Because rice and fruit (by digestion) are mainly converted into *water* ; and (by *cooling the blood*) prevent the tropical heat from feeling so oppressive.

Q. *Why are the ILL-FED instinctively averse to CLEANLINESS?*

A. Because cleanliness increases *hunger*, which they cannot allay by food.

The force of bad habits, without doubt, has more to do with this result, than the scientific fact mentioned above.

Q. *Why does the frequent use of BATHS generally tend to improve health?*

A. Because it keeps the pores of the body *free from obstruction* ; and promotes

a healthy performance of the functions of the skin.

Q. *Why are very POOR people instinctively AVERSE to VENTILATION?*

A. 1st—Because ventilation *increases the amount of oxygen in the air,—the combustion of food,—and the cravings of appetite:* and

2ndly—Ventilation *cools the air* of a room: to poor people, therefore, who are ill-clad, the *warmth* of an ill-ventilated apartment is agreeable.

Q. *Why are birds hot-blooded creatures?*

A. Because they breathe *quickly*; and the combustion of their blood is very rapid, from the abundance of oxygen introduced into their bodies.

Q. *Why are children hotter than old people?*

A. Because they breathe *more quickly*; and more oxygen is introduced into their blood to supply the capillary fire.

The heart beats more quickly in the young than in the old. The pulsations are often 140 in a minute in infants; and not more than 70 in a minute in the very aged.

Q. *Are BEARS and DORMICE colder during their winter sleep?*

A. Yes. Because their breathing and circulation almost cease.

For the same reason they are able to dispense with food for so long a time.

Q. *Why are* FROGS, FISHES, SNAKES, *and* LIZARDS COLD-BLOODED *animals?*

A. Because they consume very *little* air; and, without a plentiful supply of air, combustion is too slow to generate much animal heat.

Q. *Why is a* DEAD BODY COLD?

A. Because air is no longer conveyed to the lungs, after respiration has ceased: and, therefore, animal heat *is no longer generated by combustion.*

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## CHAPTER VII.

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# MECHANICAL ACTION.

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## I.—PERCUSSION.

Q. *How is heat produced by* MECHANICAL ACTION?

A. 1.—By Percussion. 2.—By Fric-

tion. 3.—By Condensation. And 4.—By Electricity.

Electricity only produces heat, when it meets with a bad conductor. Friction may have something to do with this.

Q. *What is meant by PERCUSSION?*

A. *The act of striking*; as when a blacksmith strikes a piece of iron on his anvil with his hammer.

Q. *Why will STRIKING IRON make it RED-HOT?*

A. Because it *condenses the particles* of the metal: and makes the latent heat *sensible*.

As a general rule sensible heat is evolved by condensation, and absorbed by expansion.

Q. *Does COLD iron contain HEAT?*

A. Yes; *every thing* contains heat; but, when a thing *feels cold*, its heat is LATENT.

Q. *What is meant by LATENT HEAT?*

A. Heat *not perceptible to our feelings*. When anything contains heat without *feeling* hotter for it, that heat is called "*latent heat*." (See p. 33.)

Q. *Does COLD iron contain latent HEAT?*

A. Yes; and when a blacksmith *compresses it by* his hammer, he brings



out latent heat; and this makes the iron red-hot.

Q. *How used blacksmiths to LIGHT their MATCHES, before the general use of lucifers?*

A. They used to place a soft iron nail upon their anvil: strike it a few times with a hammer: and the point became *sufficiently hot to light a brimstone match.*

Q. *How can a NAIL (beaten by a hammer) IGNITE a brimstone MATCH?*

A. The metal of the nail being *compressed* by the hammer, can no longer contain so much heat in a *latent state*, as it did *before*; some of it, therefore, becomes *sensible*, and increases the temperature of the iron.

Q. *Why does STRIKING a FLINT against a piece of STEEL produce a SPARK?*

A. Because it compresses those parts of the flint and steel, which strike *together*: In consequence of which, some of their latent heat is disturbed, and exhibits itself in a spark.

Q. *How does this developement of HEAT produce a SPARK, and set TINDER on fire?*

A. A very small fragment (either of

the steel or flint) *is knocked off red-hot*, and sets fire to the tinder on which it falls.

Q. *Why is it needful to keep BLOWING the TINDER with the breath?*

A. In order that the increased supply of air may furnish the tinder with more *oxygen* to assist combustion.

Q. *Where does the OXYGEN of the air COME FROM, which is blown to the lighted tinder?*

A. From the air itself, which is chiefly composed of two gases (*nitrogen and oxygen*) mixed together.

Five gallons of common air contain nearly 4 of *nitrogen*, and 1 of oxygen *mixed* together, but not chemically combined.

Q. *What is the USE of OXYGEN GAS to lighted tinder?*

A. It *supports the combustion* of the tinder. *Blowing* lighted tinder carries *oxygen* to it and *quicken*s it, in the same way as a pair of bellows quickens a dull fire.

Q. *Why do HORSES sometimes STRIKE FIRE with their FEET?*

A. Because their iron shoes strike against the flint-stones of the road; and *very small fragments* are *knocked off red-hot*, and look like sparks.

Q. *What makes these fragments RED-HOT?*

A. The percussion *condenses* the part struck : In consequence of which, some of its *latent heat* is rendered *sensible*, and exhibits itself in these red-hot fragments.

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## CHAPTER VIII.

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### 2.—FRICTION.

*What is meant by FRICTION?*

A. They take a piece of dry wood, sharpened to a point, which they rub quickly up and down a *flat piece*, till a *groove* is made ; and the *dust* (collected in this groove) *catches fire*.

Q. *Why does the dust of the wood CATCH FIRE by RUBBING?*

A. Because *latent heat* is developed from the wood *by friction*.

The best woods for this purpose are *boxwood* against *mulberry*, or *laurel* against *poplar* or *ivy*.

Q. *Do not* CARRIAGE WHEELS *sometimes* CATCH FIRE ?

A. Yes: when the wheels are *dry*,—or *fit too tightly*,—or *revolve very rapidly*.

Q. *Why* do wheels catch fire in such cases ?

A. Because the *friction* of the wheels against the *axle-tree* disturbs their *latent heat*, and produces ignition.

Q. *What is the use of* GREASING *cart wheels ?*

A. Grease *lessens the friction*; and the latent heat of the wheels is less disturbed, in consequence of this diminished friction.

Q. *Why* does RUBBING our HANDS and FACES *make them feel WARM* ?

A. 1st—Because friction *excites the latent heat* of our hands and faces, and makes it sensible to our feeling: and

2ndly—The blood is made to *circulate more quickly*; in consequence of which, the quantity of heat (left in its passage) is increased.

Q. *When a man has been almost DROWNED, why is suspended animation restored by* RUBBING ?

A. 1st—Because friction *excites the latent heat* of the half-inanimate body: and

2ndly—It makes the *blood circulate more quickly*, which increases the animal heat.

Q. *Why do two pieces of ICE (rubbed together) MELT?*

A. Ice contains 140 degrees of *latent heat*, and (when two pieces are *rubbed together*) some of this latent heat is made *sensible*, and melts the ice.

Q. *How are FORESTS sometimes set on FIRE by friction?*

A. The branches of contiguous trees (*blown about by the wind*) rub violently *against each other*, their *latent heat* is *developed* by the friction, and sets fire to the forests.

Q. *Why do carpenters' tools (such as gimlets, saws, files, &c.) become HOT when used?*

A. Because the friction of the tools against the wood disturbs *latent heat*, and makes it *sensible*.

Q. *Give an ILLUSTRATION of this.*

A. When cannon is bored, the borers become so intensely hot from friction, that they would blister the hands, if touched.

Q. *Why do these BORERS become so intensely HOT ?*

A. Because the friction of the borers against the metal is so great, that it sets free a large quantity of latent heat.

### 3.—CONDENSATION or COMPRESSION.

N. B. The reduction of matter into a smaller compass by any *external* or *mechanical* force, is called COMPRESSION.

The reduction of matter into a smaller compass by some *internal action* (as by the escape of caloric) is called CONDENSATION.

Q. *What is meant by COMPRESSION ?*

A. The act of *bringing parts nearer together*; as a sponge is *compressed* by being *squeezed in the hand*.

Q. *Can HEAT be evolved from common air merely by COMPRESSION ?*

A. Yes; if a piece of *German tinder* be placed at the *bottom of a glass tube*, and the air in the tube *compressed by a piston*, the tinder will catch fire.

In a common syringe or squirt, the *handle* part (which *contains the sucker*, and is forced up and down) is called "the Piston."

Q. *Why will the tinder catch fire ?*

A. Because the *air is compressed* ; and its *latent heat being squeezed out*, sets fire to the tinder at the bottom of the tube.

Q. *Why will small quantities of sulphur and chlorate of potash DETONATE, when rubbed together in a mortar ?*

A. Because the particles of the two substances are *compressed* so closely together, that their several *chemical affinities* are brought into action.

To "detonate" is to explode, or burn with a sudden report.

Q. *Why do DETONATING salt and powder EXPLODE, on being rubbed or struck ?*

A. Because the mechanical action of rubbing or striking, produces sufficient heat to ignite the explosive materials of which they are composed.

Q. *Why are SHOT and CANNON BALLS HEATED by being discharged from a gun ?*

A. Because they are compressed, and rubbed against the sides of the gun by the explosion of the powder.

## CHAPTER IX.

## EFFECTS OF HEAT.

## 1.—EXPANSION.

Q. *What are the principal EFFECTS of HEAT?*

A. 1.—Expansion. 2.—Liquefaction. 3.—Vaporization, and 4.—Ignition.

Q. *Shew that HEAT EXPANDS AIR.*

A. If a bladder (partially filled with air) be tied up at the neck, and *laid before a fire*, the air will expand till the bladder *bursts*.

Q. *Why will the AIR SWELL, if the bladder be laid before a fire?*

A. Because the heat of the fire will drive the particles of air *apart from each other*, and cause them to occupy more room than they did before.

Q. *Why do unslit CHESNUTS CRACK with a loud noise, when ROASTED?*

A. Because they contain a great deal of air, which is expanded by the heat of



the fire ; and (not being able to escape) *bursts* violently through the thick rind, *slitting it*, and making a great noise.

Q. *What occasions the loud CRACK or report, which we hear ?*

A. 1st—The *sudden bursting of the rind* makes a report ; in the same way as a piece of *wood or glass* would do, if *snapped in two* : and

2ndly—The *escape of hot air* from the chesnut makes a report also ; in the same way as the escape of the gases formed by the explosion of gunpowder does.

Q. *Why does the sudden bursting of the rind, or snapping of a piece of wood, make a REPORT ?*

A. Because a *violent jerk* is given to the air, when the attraction of cohesion is thus suddenly overcome : This jerk produces *rapid undulations* in the air, which (striking upon the ear) cause the sensation of *sound*.

Q. *Why does the escape of air from the chesnut, or the explosion of gunpowder, produce a REPORT ?*

A. Because the sudden expansion of the imprisoned air, produces a partial

vacuum: The *report* is caused by the rushing of *fresh air* to fill up this vacuum.

See Thunder, p. 8.

Q. *If a CHESNUT be SLIT, it will NOT crack; why is this?*

A. Because the *heated air* of the chesnut can then *freely escape* through the *slit in the rind*.

Q. *Why does an APPLE split and spurt about, when roasted?*

A. In some measure from the *expansion* of *air by heat*; but more especially because its *juice* is converted into *steam*.

Q. *How is the JUICE of an APPLE confined in the fruit?*

A. By being placed in numerous *little cells* (like those of an honey-comb): When the *juice* is converted into *steam*, it bursts through these cells; and forces those parts which oppose it, through the peel.

Q. *When an APPLE is ROASTING, why is one part made soft, while the rest remains hard?*

A. Because the *vegetable matter* of the part nearest the fire is cooked by the *steam* of the hot juices: and where

the heated air and steam break through and escape, the apple *collapses* and becomes soft.

Q. *What is meant by the "apple COLLAPSING?"*

A. It means that the *plumpness* gives way, and the apple becomes *flabby* and *shrivelled*.

Q. *Why do SPARKS of fire start (with a crackling noise) from pieces of WOOD laid upon a FIRE?*

A. Because the *air* (expanded by heat) *forces its way* through the *pores of the wood*; and carries along with it the *covering* of the *pore*, which resisted its passage.

The conversion of the woody fibre of the interior parts into combustible gases, contributes to this effect.

Q. *What is meant by the "PORES of the wood?"*

A. Very small *holes in the wood*, through which the *sap* circulates.

Q. *What are the SPARKS of fire, which burst from the WOOD?*

A. Very small pieces of wood made *red-hot*, and separated from the log by the *force of the air*, when it bursts from its confinement.

Q. *Why does DEAL make more snapping than any other wood?*

A. Because the pores of deal are *very large*, and contain *more air* than those of wood having a *closer grain*.

Q. *Why does GREEN wood make less snapping, than DRY?*

A. Because the pores contain *less air*, being filled with *sap*.

Q. *Why does DRY wood make more snapping than green?*

A. Because the sap is *dried up*, and the pores are filled with *air* instead.

Q. *Why does DRY wood BURN more easily than green or wet wood?*

A. Because the pores of green or wet wood are filled with *moisture*, which extinguishes flame; whereas the pores of dry wood are filled with *air*, which supports combustion.

Q. *Why does MOISTURE extinguish flame?*

A. 1st—Because it prevents the *carbon* and *hydrogen* of the fuel from uniting with the *oxygen* of the air, to form *carbonic acid gas* and water: and

2ndly—Because heat is perpetually carried off, by the formation of the sap *into steam*.

Q. *Why do STONES snap and fly about, when heated in the fire ?*

A. Because the close texture of the stone prevents the hot air from escaping ; in consequence of which, it *bursts forth with great violence*, tearing the stone to atoms, and forcing fragments into the room.

Probably some part of this effect is due to the setting free of the *water of crystallization*.

Q. *When bottled ale or porter is set before a fire, why is the CORK forced out sometimes ?*

A. Because the *carbonic acid* of the liquor *expands* by the heat, and drives out the cork.

Carbonic acid gas is a compound of carbon and oxygen. All fermented liquors contain more or less of carbonic acid gas ; bottled ale or porter a large quantity.

Q. *Why does ale or porter FROTH more, after it has been set before a fire ?*

A. Because the heat of the fire sets free the *carbonic acid* ; which is entangled as it rises through the liquor, and produces bubbles or froth.

Q. *When a boy makes a BALLOON, and sets fire to the cotton or sponge (which has been steeped in spirits of wine), why is the balloon INFLATED ?*

A. Because the *air* of the balloon is *expanded by the flame*, till every part is inflated and the paper made smooth.

Q. *Why does the balloon RISE, after it has been inflated by the expanded air?*

A. Because the same quantity of air is expanded to *three or four times* its *original volume*; and made so much *lighter*, that even when all the paper, wire, and cotton are added, it is still lighter than common air.

The balloon ascends in consequence of the pressure from beneath of the heavier cold air by which it is surrounded, in the same way as the hot air in a chimney.

Q. *Why does a SMOKE-JACK turn round in a chimney?*

A. Because the *current* of *hot air* up the chimney (striking against the oblique vanes of the smoke-jack) drives them round; as wind drives round the sails of a mill.

Q. *Which EXPAND the most under the SAME DEGREE of heat—gases, liquids, or solids?*

A. Gases: all of which expand in the same ratio from heat.

Q. *What degree of expansion in gases is caused by heat?*

A. 481 degrees of heat will make a volume of gas twice as large as it was before.

Q. *What is the difference between a VAPOUR and a GAS?*

A. A VAPOUR is an elastic aeriform fluid, which may readily be converted into a liquid or solid merely by *change of temperature* :

A. A GAS is an elastic aeriform fluid, which cannot be made to change its state, except by the application of *artificial pressure and intense cold*.

Carbonic acid gas has even been converted into the solid form by the use of these means.

The vapour produced by the boiling of water is called *steam*.

Q. *What would gases be at VERY LOW temperatures?*

A. All gases would *probably* be *liquid at extremely low temperatures* ; but the most *intense cold* hitherto artificially produced, has not been sufficient to reduce some of the gases to a liquid state.

Gases which cannot by our present means be brought into the liquid form, are called '*permanent*,' to distinguish them from vapours.

Q. *Why are some things SOLID, others LIQUID, and others GASEOUS?*

A. Because the particles which compose some things are nearer together than they are in others.—Those in which the particles are *closest* are *solid*: those in which they are *furthest apart* are *gaseous*; and the rest *liquid*.

Q. *Why does heat change a SOLID (like ice) first into a LIQUID, and then into a GAS?*

A. Because it drives the component particles further *asunder*; hence a certain quantity of heat changes solid ice into a *liquid*,—and a further addition of heat changes the liquid into *steam*.

Q. *Why does water SIMMER before it boils?*

A. Because the particles of water near the *bottom* of the kettle (being formed into steam sooner than the rest) *shoot upwards*; but are *condensed* again by the *colder surface of the water*, and produce what is called “simmering.”

Q. *What is meant by SIMMERING?*

A. A gentle tremor or *undulation* on the surface of hot water. When water *simmers*, the bubbles *collapse beneath the*



*surface, and the steam is condensed to water again ; but when water boils, the bubbles rise through the surface, and the steam is thrown off.*

Q. *Why does a KETTLE SING, when the water simmers ?*

A. Because the entangled air escapes by *fits and starts* from the surface of the water ; producing the noise called “ singing.”

Q. *Why does NOT a kettle SING, when the water boils ?*

A. Because *all* the water is *boiling hot* ; so the steam escapes in large quantities from the entire surface, and not by *fits and starts*.

Q. *When does a kettle sing MOST ?*

A. When it is set on a *hob* to boil.

Q. *Why does a kettle SING MORE, when it is set on the SIDE of a fire, than when it is set in the MIDST of a fire ?*

A. Because the heat is applied *unequally*, and one side being made hotter than the other ; the water takes longer time to boil.

Q. *Why does a KETTLE sing, when the boiling water begins to COOL again?*

A. Because the *upper* surface cools *first*; and the steam (which rises from the lower part of the kettle) is *again* partially condensed, and escapes by *fits*, and *starts*.

Q. *Why does BOILING water increase in bulk?*

A. Because it is *expanded by the heat*: i. e.—The heat of the fire drives the particles of water *further apart* from each other: and (as they are not *packed so closely together*) they take up *more room*.

Q. *What is meant when it is said, “that HEAT drives the PARTICLES of water further APART from each other?”*

A. Water is composed of little globules, like very small grains of sand; the heat *drives* these particles apart from each other, and (as they then require more *room*) the water increases in bulk.

Q. *Why does boiling water BUBBLE?*

A. Because the heated air and *vapour* (rising through the water) force up bubbles in their effort to escape.

Q. *Why does a KETTLE sometimes BOIL OVER?*

A. Because the water is *expanded by heat*; if, therefore, a kettle is filled with *cold water*, some of it must *run over*, as soon as it is *expanded by heat*.

Q. *But I have seen a kettle BOIL OVER, although it has not been filled FULL of water; how do you account for this?*

A. If a *fire* be fierce, the *air* and *vapour* are expelled so *rapidly*, that the *bubbles are very numerous*; and since these carry portions of the water with them, some of it runs over.

Q. *Why is a pot (which was full to OVERFLOWING, while the water was boiling HOT) NOT FULL, after it has been taken off the fire for a short time?*

A. Because (while the water is *boiling*) it is expanded by the heat, and fills the pot even to overflowing; but, when it becomes cool, it *contracts* again, and occupies a less space.

The cooling of the water prevents any further escape of steam; and the generation of steam is one cause of the expansion of hot water.

Q. *Why does the water of a KETTLE sometimes run out of the SPOUT, when it BOILS?*

A. Because when the lid fits tightly,

the steam cannot lift it up and escape ; being confined, therefore, in the kettle, it *presses on the water* and forces it out of the spout.

Q. *What causes the RATTLING NOISE, often made by the LID of a saucepan or boiler ?*

A. The steam (seeking to escape) *forces up the lid* of the boiler, and the *weight* of the lid carries it *back again* ; this being done *frequently*, produces a rattling noise.

Q. *If the steam could NOT LIFT UP the lid of the boiler, how would it escape ?*

A. If the lid fitted so tightly, that the steam could not raise it up, the boiler would *burst*, and the consequences might be serious.

Q. *When steam pours out from the spout of a kettle, the STREAM begins apparently HALF AN INCH off the SPOUT ; why does it not begin CLOSE to the spout ?*

A. Steam is really *invisible* ; and the half-inch (between the spout and the “ *stream of mist*”) is the *real steam*, before it has been condensed by the air.

Q. *Why is not ALL the steam INVISIBLE, as well as that half-inch ?*

A. Because the invisible particles are condensed by the *cold air* ; and, rolling one into another, look like mist.

Q. *What BECOMES of the STEAM, for it soon vanishes ?*

A. After it has been condensed into mist, it is *dissolved by the air*, and dispersed abroad as *invisible vapour*.

Q. *And what BECOMES of the invisible vapour ?*

A. Being *lighter* than air, it *ascends* to the upper regions of the atmosphere, where (being again *condensed*) it contributes to form *clouds*.

Every portion of the atmosphere contains more or less invisible vapour, varying from day to day with the state of the weather.

Q. *Why does a METAL SPOON (left in a saucepan) RETARD the process of boiling ?*

A. Because the metal spoon (being an excellent *conductor*) *carries off the heat from the water* ; and (as heat is carried off by the spoon) the water takes a longer time to boil.

Q. *Why will a pot (filled with water) NEVER BOIL, when immersed in another vessel full of water also ?*

A. Because water contained in an

open vessel can never be heated *above the boiling point*; all the heat absorbed by water after it *boils*, is employed in generating *steam*.

Q. *How does the conversion of water into steam, prevent the INNER pot from boiling?*

A. Directly the water in the larger pot is *boiling hot* (or  $212^{\circ}$ ), *steam is formed*, and carries off *some of its heat*; therefore, 212 degs. of heat can never *pass through it*, to raise the *inner vessel to boiling heat*.

Q. *Why do SUGAR, SALT, &c. RETARD the process of boiling?*

A. Because they increase the *density* of water; and whatever increases the *density* of a fluid, retards its boiling.

Q. *If you want water to boil without coming in contact with a SAUCEPAN, what plan must be adopted?*

A. We must *immerse the pot* (containing the water to be boiled) in a saucepan containing *strong brine*, or sugar.

Q. *Why would the INNER vessel boil, if the OUTER vessel contained strong BRINE?*

A. Because *brine* will not boil, till it is raised to 218 or 220 degs. Therefore,

212 *deg*<sup>s</sup> of heat may easily pass through it, to raise the vessel immersed in it to boiling heat.

Q. *Why will brine impart to another vessel MORE than 212°, and water NOT SO MUCH?*

A. Because no liquid can impart so high a degree of heat, as its own *boiling* temperature: As water boils at 212°, it cannot impart 212° of heat: but, as brine will not boil without 218° of heat, it can impart enough to make water boil.

Q. *Why can liquids impart no EXTRA heat, after they boil?*

A. Because all *extra* heat is spent in *making steam*. Hence water will not boil a vessel of *water* immersed in it, because it cannot impart to it 212 *deg*<sup>s</sup> of heat; but *brine* will, because it can impart *more* than 212 *deg*<sup>s</sup> of heat, before it is *itself* converted into steam.

|                       |                  |                     |     |
|-----------------------|------------------|---------------------|-----|
| Ether boils at about  | 96 <i>degs</i> . | Syrup boils at .    | 221 |
| Alcohol . . . .       | 176              | Oil of turpentine . | 316 |
| Water . . . .         | 212              | Sulphuric acid .    | 472 |
| Water, with one-fifth |                  | Linseed oil . .     | 640 |
| salt . . . .          | 219              | Mercury . . .       | 662 |

Any liquid which boils at a *lower* degree can be made to boil, if immersed in a liquid which boils at a *higher* degree. Thus a *cup of ether* can be made to boil in a saucepan of *water*. A *cup of water*, in a saucepan of *brine* or *syrup*. But a *cup of water* will *not* boil, if immersed in *ether*; nor a *cup of syrup*, in *water*.

Q. *Why are clouds* HIGHER *on a FINE day?*

A. Because they are *lighter*, and *more buoyant*.

Q. *Why are clouds* LIGHTER *on a FINE day?*

A. 1st—Because the vapour of the clouds is *less condensed*; and

2ndly—The *air* itself (on a fine day) retains more of its vapour in an *invisible* form.

Q. *Why is a CUP put* INVERTED *into a fruit pie?*

A. Its principal use is to hold the *crust up*, and prevent it from *sinking*, when the cooked fruit gives way under it.

Q. *Does not the cup* PREVENT *the fruit of the pie from* BOILING OVER?

A. No,—it will rather tend to *make* it boil over, as there will be *less room* in the dish.

Q. *Explain this.*

A. When a pie is put into an oven, the *air* in the cup will *begin to expand*, and drive every particle of juice from under it; in consequence of which, the pie-dish will have a cup-full *less room* to hold its fruit in, than if the cup were *taken out*.

Some of the heated air is driven from the cup, and escapes in



bubbles through the juice, and out of the pie altogether. The place of this is occupied by juice when the pie cools.

Q. *If the juice is driven OUT of the cup; why is the CUP always FULL of juice, when the pie is cut up?*

A. Because immediately the pie is "*drawn*," the air in the cup begins to *contract again*, and occupy a *smaller space*; and, as the cup is no longer full of *air*, *juice* rushes in to occupy the void.

Q. *Why does juice rush into the cup, when the cup is NOT FULL of AIR?*

A. Because the external air presses upon the *surface of the juice*, which rushes *unobstructed* into the cup; as mercury rises through the tube of a barometer.

N. B. Since the juice of the pie runs into the cup, as soon as it is taken out of the oven, the cup prevents the juice from being *spilt over the crust*, when the pie is carried about from place to place; although it does not prevent the fruit from boiling over.

## CHAPTER X.

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### EXPANSION FROM HEAT.

(Continued.)

Q. *Does heat expand every thing ELSE, besides air and water?*

A. Yes: *every* thing (that man is acquainted with) is expanded by heat.

Q. *Why does a COOPER heat his HOOPS RED-HOT, when he puts them on a tub?*

A. 1st—As iron *expands by heat*, the hoops will be *larger* when they are red-hot; in consequence of which, they will fit on the tub *more easily*: and

2ndly—As iron *contracts by cold*, the hoops will *shrink* as they cool down, and girt the tub with a *tighter grasp*.

Q. *Why does a WHEELWRIGHT make the iron hoop or "tire" RED-HOT, which he fixes on a WHEEL?*

A. 1st—That it may fit on *more easily*: and

2ndly—That it may girt the wheel *more tightly*.

Q. *Why will a wheelwright's HOOP FIT the wheel MORE EASILY, for being made RED-HOT?*

A. Because it will be *expanded* by the heat; and (being larger) will go on the wheel *more easily*.

Q. *Why will the HOOPS, which have been put on HOT, GIRT the wheel more FIRMLY?*

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A. Because they will *shrink* as they cool; and, therefore, *girt the wheel* with a *tighter grasp*.

Q. *Why does a STOVE make a CRACKLING NOISE, when a fire is very hot?*

A. Because it *expands* from the heat; and the parts of the stove *rubbing* against each other, or driving against the *bricks*, produce a *crackling* noise.

Q. *Why does a STOVE make a similar CRACKLING NOISE, when a large fire is TAKEN DOWN?*

A. Because it *contracts again*, when the fire is removed; in consequence of which, the parts *rub against* each other again, and their connection with the bricks is *again disturbed*.

Q. *Why does the PLASTER round a stove CRACK and fall away?*

A. Because (when the fire is lighted) the *iron-work* expands more than the brick-work and plaster, and *pushes them away*; but (when the fire is put out) the metal *shrinks* again, and leaves the “setting” behind.

The “setting” is a technical word for the plaster, &c. in immediate contact with the stove.

Q. *Why does the plaster FALL AWAY?*

A. As a *chink* is left (between the "setting" and the stove), the plaster will frequently fall away from its own weight.

Q. *What OTHER cause contributes to BRING the PLASTER DOWN?*

A. As the *heat* of the fire varies, the *size* of the iron stove varies also; and this expanding and contracting keep up such a *constant disturbance* about the plaster, that it *cracks and falls off*.

Q. *Why does the MERCURY of a THERMOMETER RISE in hot weather?*

A. Because heat *expands the metal*, which (being increased in bulk) occupies a *larger space*; and, consequently, rises higher in the tube.

Q. *Why is a GLASS BROKEN, when HOT WATER is poured into it?*

A. Because the *inside* of the glass is suddenly more expanded by the hot water than the *outside*; and in consequence of this unequal expansion the *glass snaps*.

Q. *Why is not the OUTSIDE of the glass expanded by hot water, as much as the INSIDE ?*

A. Because glass is a bad conductor of heat, and *breaks* before the heat of the *inner* surface is conducted to the *outside*.

Q. *Why does a glass snap, because the INNER surface is HOTTER than the OUTER ?*

A. Because the *inner* surface is expanded, and not the *outer* : in consequence of which, an *opposing force* is created, which breaks the glass.

Q. *Why is a CHINA CUP broken, if HOT WATER be poured over it, or into it ?*

A. Because china is a bad conductor; and, as the *inner* surface expands from the heat more than the *outer*, an *opposing force* is created, which breaks the cup.

Q. *If a glass beaker be set on a warm HOB, why does the BOTTOM COME OFF ?*

A. Because glass is a bad conductor; and (as the *bottom* of the glass expands from the warmth of the hot stove, before the *sides* are heated) the two parts *separate* from each other. •

## CHAPTER XI.

## 2.—LIQUEFACTION.

## 3.—VAPORIZATION.

Q. *What is meant by LIQUEFACTION ?*

A. The conversion of a *solid* into a *liquid* by the agency of heat : as solid ice is converted into water by the heat of the sun.

Q. *Why is ice MELTED by the HEAT of the SUN ?*

A. Because the heat of the sun *forces its particles asunder* ; till their attraction of cohesion is sufficiently overcome, to *convert the solid ice into a liquid.*

See p. 115.

Q. *Why are METALS MELTED by the heat of FIRE ?*

A. Because the heat of the fire *forces their particles asunder* ; till their attraction of cohesion is sufficiently overcome, to *convert the solid metal into a liquid.*

Q. *Why is WATER converted into STEAM by the heat of the FIRE ?*

A. Because the heat of the fire



*separates its globules into very minute bubbles ; which (being lighter than air) fly off from the surface in the form of steam.*

Q. *Why does not WOOD MELT, like metal ?*

A. Because the heat of the fire *decomposes* the wood into *gas, smoke, and ashes ;* and the different parts *separate* from each other.

Q. *What is meant by VAPORIZATION ?*

A. The *conversion* of a *solid or liquid* into *vapour*: as snow or water is converted into vapour by the heat of the sun.

Q. *What are CLOUDS ?*

A. Moisture *evaporated* from the *earth*, and again partially *condensed* in the upper regions of the air.

Q. *What is the difference between a FOG and a CLOUD ?*

A. Clouds and fogs differ only in one respect. *Clouds* are *elevated above our heads*: but *fogs* come in contact with the *surface of the earth*.

Q. *Why do clouds FLOAT so readily in the air ?*

A. Because they are composed of

*very minute globules (called vesicles); which (being lighter than air) float, like soap bubbles.*

Q. *Why does VAPOUR sometimes form into CLOUDS, and sometimes rest upon the earth as MIST or FOG?*

A. This depends on the *temperature* of the air. When the *surface of the earth* is *warmer than the lower air*, the vapour of the earth (being condensed by the chill air) becomes *mist or fog*. But, when the *lower air* is *warmer than the earth*, the vapour rises *through the air*, and becomes cloud.

Q. *Are ALL clouds ALIKE?*

A. No. They vary greatly in *density, height and colour*.

Q. *What is the chief CAUSE of fog and clouds?*

A. The changes of the wind.

Many *local* circumstances also favour the formation of clouds.

Q. *How can the CHANGES of the WIND affect the CLOUDS?*

A. If a *cold current of wind* blows suddenly over any region, it *condenses* the invisible vapour of the air into *cloud or rain*: but if a *warm current of wind*

blows over any region, it *disperses* the clouds, by *absorbing their vapour*.

Q. *What countries are the MOST cloudy?*

A. Those where the winds are *most variable*, as Britain.

Q. *What countries are the LEAST cloudy?*

A. Those where the winds are *least variable*, as Egypt.

Q. *What DISTANCE are the CLOUDS from the EARTH?*

A. Some *thin light clouds* are elevated above the highest mountain-top; some *heavy* ones touch the steeples, trees, and even the earth: but the *average* height is between *one and two miles*.

N. B. Streaky curling clouds, *like hair*, are often 5 or 6 miles high.

Q. *WHAT clouds are the LOWEST?*

A. Those which are *most highly electrified*: lightning clouds are rarely more than about 700 yards above the ground; and often actually *touch the earth with one of their edges*.

Q. *What is the SIZE of the CLOUDS?*

A. Some clouds are 20 *square miles* in surface, and above a mile in

while others are only a *few yards or inches*.

Q. *How can persons ascertain the THICKNESS of a cloud?*

A. As the *tops* of high mountains are generally above the clouds, travellers may pass quite through them into a clear blue firmament; when the clouds will be seen *beneath their feet*.

Q. *What produces the great VARIETY in the SHAPE of the clouds?*

A. Three things: 1st—The cause and manner of their *formation*:

2ndly—Their *electrical* condition: and

3rdly—Their relations to *currents of wind*.

Q. *How can ELECTRICITY affect the SHAPE of clouds?*

A. If one cloud be *full of electricity* and another *not*, they will be *attracted* to, each other, and either coalesce,—diminish in size,—or vanish altogether.

Q. *WHAT clouds assume the most FANTASTIC shapes?*

A. Those that are the most *highly*

Q. *What effect have WINDS on the SHAPE of clouds ?*

A. They sometimes *absorb them entirely* : sometimes *increase their volume and density* ; and sometimes *change the position of their parts*.

Q. *How can winds ABSORB clouds altogether ?*

A. *Warm dry winds* will convert the substance of clouds into *invisible vapour*, which they will carry away in their own current.

Q. *How can winds INCREASE the bulk and density of clouds ?*

A. *Cold currents of wind* will condense the *invisible vapour* of the air, and *add it to the clouds* with which they come in contact.

Q. *How can winds CHANGE the SHAPE of clouds, by altering the position of their parts ?*

A. Clouds are so *voluble and light*, that every breath of wind changes the position of their *vesicles or bubbles*.

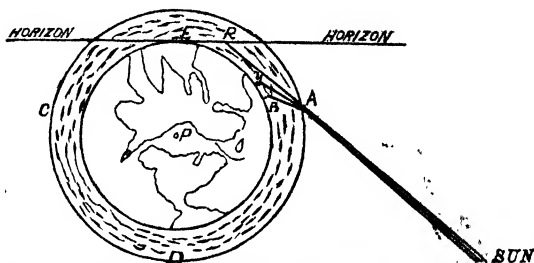
Q. *What are the general COLOURS of the clouds ?*

A. *White and grey*, when the sun is *above the horizon* : but *red, orange, and yellow*, at *sun-rise, and sun-set*.

*The blue sky is not cloud at all.*

**Q.** *Why are the LAST clouds of evening generally of a RED tinge?*

**A.** Because the *red* rays, being less *refrangible* than the *yellow* or *blue* rays, remain longest in sight, as the surface of the earth turns away from the sun.



Every beam of light is composed of three coloured rays, blue, yellow, and red. As the beam passes through the atmosphere *A*, these are separated from each other. The blue being drawn most down, the yellow next, and the red least. As the earth with its clouds and atmosphere turn round the pole *P*, in the direction *A C D*; any given cloud would pass first under; the blue rays at *B*, then the yellow rays at *Y*, and then the red rays at *R*; and be tinged by their respective colours. An observer placed at *E*, just as he was turning into darkness towards *C*, would see the clouds tinged red at *R*, resting upon the western horizon.

**Q.** *Why are the EARLY morning clouds generally RED?*

**A.** Because the *red* rays, being less *refrangible* than the *yellow* or *blue* rays, come soonest into sight, as the surface of the earth turns into daylight. N 2

Suppose the earth to be turning in the direction D C A. Then any given cloud would come first into the light of the red rays R, and the observer at E would see it so tinged on the eastern horizon, just as he was coming into daylight.

Q. *What is the cause of* MORNING TWILIGHT?

A. Some of the rays of *light* which strike the top of the atmosphere, are bent down while the sun is still *invisible* beneath the horizon.

Q. *What is the cause of* EVENING TWILIGHT?

A. Some of the *rays of light* which strike the top of the *atmosphere* are bent down, when the sun has sunk out of sight beneath the horizon.

Q. *Why is not the colour of clouds always* ALIKE?

A. Because the *condition* of the *atmosphere* is continually *varying*, as also the *size, density*, and relative *position* of the clouds with regard to the sun: so that sometimes *one* colour is reflected, and sometimes *another*.

Q. *What regulates the* MOTION *of the clouds?*

A. Principally the *winds*; but sometimes *electricity* will influence their motion also.

Q. *How do you know that clouds move by OTHER influences besides WIND?*

A. Because (in calm weather) we often see *small clouds meeting each other from opposite directions.*

Q. *How do you know that ELECTRICITY affects the motions of the clouds?*

A. Because clouds often meet from *opposite directions*; and, having discharged their opposite electricities into each other, *vanish altogether.*

Q. *Into how many CLASSES are the different sorts of clouds generally divided?*

A. Into three classes :—viz. Simple, Intermediate, and Compound.

Q. *How are SIMPLE clouds sub-divided?*

A. Into 1.—Cirrus; 2.—Cum'ulus; and 3.—Stra'tus clouds.

Q. *What sort of clouds are called CIRRUS?*

A. Clouds like *fibres, loose hair, or thin streaks*, are called "cirrus clouds."

Q. *Why are these clouds called CIRRUS?*

A. From the Latin word *cirrus* ("a lock of hair, or curl"): Cirrus clouds are the *most elevated of all.*



Q. *What do CIRRUS clouds PORTEND?*

A. Fine weather. Whenever *cirrus clouds* appear, there is but little moisture in the air, and this is only slowly condensed in the higher regions of the atmosphere.

Q. *What sort of clouds are called CUM'ULUS?*

A. Cum'ulus clouds are lumps, like great *sugar-loaves*,—*volumes of smoke*,—or *mountains towering over mountains*.

Q. *Why are these monster masses called CUM'ULUS clouds?*

A. From the Latin word *cum'ulus* ("a mass or pile").

Q. *What do CUM'ULUS clouds FORESHOW?*

A. When these piles of cloud are *fleecy*, and sail *against the wind*, they indicate *rain*; but when their outline is very *hard*, and they come up *with the wind*, they foretell *fine weather*.

Cum'ulus clouds should be *smaller* towards evening than they are at noon. If they *increase* in size at sun-set, a thunder-storm may be expected in the night.

Q. *What sort of clouds are called STRA'TUS?*

A. *Creeping mists*, especially prevalent in a summer's evening: these clouds

rise at sun-set in *low damp places* ; and are always *nearer the earth*, than any *other* sort of cloud.

Q. *Why are these mists called STRATUS clouds ?*

A. From the Latin word *stra'tus* ("laid low," or "that which lies low").

Q. *What produces CIRRUS clouds ?*

A. Moisture in a visible form, deposited in the *higher regions* of the atmosphere from *ascending currents* of *heated air*.

Q. *What produces CUMULUS clouds ?*

A. Masses of visible vapour passing from the places where they were *formed*, to other places where they are about to be either *dissolved*, or deposited as *falling rain*.

Q. *What produces STRATUS clouds ?*

A. Beds of visible moisture, formed by some chilling effects, acting along the *direct surface* of the *earth*.

Q. *How are the INTERMEDIATE clouds subdivided ?*

A. Into two sorts. 1.—The Cirro-Cum'ulus ; and 2.—The Cirro-Strat'us.

Q. *What are CIRRO-CUM'ULUS CLOUDS ?*

A. Cirro-Cum'ulus clouds are cirrus clouds springing from a *massy centre*; or *heavy masses*, edged with *long streaks* generally called "*mares' tails*."

A system of *small round* clouds may be called cirro-cum'ulus.

Q. *What do CIRRO-CUM'ULUS clouds generally FOREBODE ?*

A. Continued drought, or hot dry weather.

Q. *What are CIRRO-STRA'TUS CLOUDS ?*

A. They compose what is generally called a "*mackarel sky*." This class of clouds invariably indicates *rain* and *wind*; hence the proverb—

"Mackarels' scales and mares' tails  
Make lofty ships to carry low sails."

Q. *What produce CIRRO-CUM'ULUS clouds ?*

A. *Cum'ulus* clouds dissolving away into *cirrus* produce the intermediate class, called CIRRO-CUM'ULUS.

Q. *What produce CIRRO-STRA'TUS clouds ?*

A. *Cirrus* clouds accumulating into *denser* masses produce the intermediate class, called CIRRO-STRATUS.

Q. *How are COMPOUND clouds sub-divided ?*

A. Compound clouds are sub-divided into 2 sorts. 1.—The Cum'ulo-Stra'tus; and 2.—The Nimbus clouds.

Q. *What is meant by CUM'ULO-STRA'TUS clouds?*

A. Those clouds, which assume all sorts of *gigantic forms*; such as vast towers and rocks,—huge whales and dragons,—scenes of battle,—and cloudy giants. This class of clouds is the most romantic and strange of all.

Q. *What do the CUMULO-STRA'TUS clouds FORETELL?*

A. A *change of weather*; either from fine to rain, or from rain to fine.

Q. *What are NIMBUS clouds?*

A. All clouds from which *rain falls*. Nimbus is the Latin word for "*clouds which bring a storm.*"

Q. *By what particular character may the NIMBUS (or rain-cloud) be at once distinguished?*

A. By the want of a *defined outline*: Its edge is gradually shaded off from the *deep grey mass into transparency*.

Q. *What APPEARANCE takes place in the clouds, at the approach of RAIN?*

A. The *cum'ulus* cloud becomes *stationary*, and *cirrus streaks* settle upon it, forming *cum'ulo-stra'tus* clouds; *black* at first, but afterwards of a *grey* colour.

Q. *Why do clouds gather round MOUNTAIN TOPS?*

A. Because the air (being *chilled* by the cold mountain tops) deposits its vapour there, in a *visible form* or cloud.

Q. *What are the USES of CLOUDS?*

A. 1st—They act as *screens*, to arrest the radiation of heat from the earth;

2ndly—They temper the heat of the *sun's rays*; and

3rdly—They are the great *store-houses of rain*.

“Radiation of heat,” i. e. the escape of heat, when no *conductor* carries it away.

Q. *Why is WIND said to BLOW UP the clouds?*

A. Because a *dry warm* wind (which has travelled over seas) having absorbed a large quantity of moisture, deposits some of it in the *visible form of clouds*, as soon as it reaches a *colder* region of air.

Q. *Why does WIND sometimes DRIVE AWAY the clouds ?*

A. Because it has travelled over *dry climes* or *thirsty deserts*, and become so *dry*, that it absorbs vapour from the clouds, and causes them to disappear.

Q. *What is the CAUSE of a RED sunset ?*

A. The vapour of the air not being *actually condensed into clouds*, but only on the *point of being condensed*.

Q. *Why is a RED sunset an indication of a FINE DAY to-morrow ?*

A. Because the vapours of the earth are *not condensed into clouds*, even by the cold of sunset. Our Lord referred to this prognostic in the following words : "When it is evening ye say it will be fair weather, for the sky is red." (Mat. xvi. 2.)

Q. *What is the cause of a coppery YELLOW SUN-SET ?*

A. The vapour of the air being *actually condensed into clouds*.

Q. *Why do vapours (NOT actually condensed); refract RED rays, while condensed vapour refracts yellow ?*

A. Because the beams of light meet with very little resistance; in consequence of which, those rays are bent down to the eye, which require the least refraction, such as *red*.

See figure on p. 135, where it is evident that the *red* ray A R, is less bent, than the yellow and blue rays, A Y, A B.

Q. *Why do CONDENSED vapours refract YELLOW rays, whereas vapours not actually condensed refract red ?*

A. Because the beams of light meet with *more resistance* from the condensed vapour; in consequence of which, those rays are bent down to the eye, which are *more refracted* than the red, such as yellow.

See figure on p. 135, where it is evident that the yellow ray A Y, is more bent than the red ray, A R.

Q. *Why is a YELLOW SUN-SET an indication of WET ?*

A. Because it shows that the vapours of the air *are already condensed into clouds*; rain, therefore, may be shortly expected.

Q. *What is the cause of a RED SUN-RISE ?*

A. Vapour in the upper region of the air *just on the point of being condensed*.

Q. *Why may a red and lowering sky at morning be an indication of approaching RAIN ?*

A. Because the *density* of the air is due to an excess of vapour at the *point of condensation* ; hence our Lord's observation, " In the morning ye say, it will be foul weather to-day, for the sky is red and lowering." (Matt. xvi., 3.)

Professor Forbes has seen red light in the jet of steam issuing from the valve of a locomotive, where it is just becoming visible from condensation. Professor Griffiths states, that the red and lowering morning sky, which indicates foul weather, *probably* depends upon excess of vapour in the atmosphere : but as a general rule, dry air is less transparent than moist, and red rays have more power to pierce through a dense atmosphere : hence the sun is red at rising or setting, or in a fog.

Q. *Why is a grey sun-rise often indicative of a FINE day ?*

A. Because at the instant of sun-rise the higher regions of the air are comparatively *free* from moisture, and feeble white light can pass through.

Grey is only white in a diluted state.

Q. *Why is a yellow tint in the sky indicative of the approach of WET ?*

A. Because it shows that the air is *moist*. Moist air is more transparent than dry, and allows yellow rays, which have *less momentum* than red, to pass through as well.



Q. *What difference (in the state of the air) is required to make a GREY and RED sun-rise?*

A. In a *grey* sun-rise, the air is sufficiently clear to allow the *three* coloured rays to pass with a feeble degree of intensity. In a *red* sun-rise, the air is so dense that it stops all but the red rays. Hence the proverb—

“Evening red and morning grey,  
Will set the traveller on his way;  
But evening grey and morning red,  
Will bring down rain upon his head.”

Q. *Why is the sky BLUE?*

A. Because the *weak* blue rays, which are reflected *upwards* from the earth, cannot get through the air, and are therefore sent *down* again.

It is, properly, the air which is blue. Hence the sky becomes of a deeper colour, as we ascend high mountains.

Q. *The proverb says, “A rainbow in the MORNING is the shepherd’s warning:” Why is it so?*

A. Because a *morning* rainbow must be always in the *west*; and indicates, that bad weather is on the road to us.

Q. *Why must a MORNING rainbow be always in the WEST?*

A. Because the sun is in the *east*;

and a rainbow can be formed only when the rainy clouds are *opposite* to the sun.

Q. *Why does a rainbow in the WEST indicate that BAD WEATHER is on the road to us?*

A. Because our heavy rains are usually *brought by west or south-west winds*; and clouds which reflect the colour of the rainbow *in the west*, must be coming up *with the wind*.

This will not be true if the wind be easterly.

Q. *The proverb says, "A RAINBOW at NIGHT, is the shepherd's delight:" Why is it so?*

A. Because a rainbow at *night* is in the *east*; and indicates, that bad weather is *leaving* us.

Q. *Why must a rainbow at NIGHT be always in the EAST?*

A. Because the sun is in the *west*; and a rainbow can be formed only when the rainy clouds are *opposite* to the sun.

Q. *Why does a rainbow in the EAST indicate that bad weather is LEAVING us?*

A. Because our rain is generally brought by *west and south-west winds*; when, therefore, the clouds (which reflect the rainbow) have been driven from the

*west to the east, it is a plain proof that they have already passed over us, and are going away.*

This will not be true if the wind be easterly.

**Q.** *What is meant by an AURORA BOREA'LIS, or northern light?*

**A.** *A luminous appearance in the north of the sky at night-time. Sometimes streaks of blue, purple, green, red, &c., and sometimes flashes of light are seen.*

As these streams of light have a tremulous motion, they are called in the Shetland Isles, "Merry dancers."

**Q.** *Describe the appearance of the Aurora Borealis, visible in England on the night of Nov. 17th, 1848.*

**A.** *The sky overhead seemed in flames, and bands of various colours rose from the horizon to the North Star, forming a luminous arch. This magnificent appearance lasted from 7 till 10 o'clock at night.*

**Q.** *Is this the usual appearance of the Aurora Borealis in our island?*

**A.** *No. It is generally a luminous white band on the top of a pitchy dark*

cloud,—low down in the horizon,—and running from east to west of the due north.

Q. *What is the cause of the AURORA BOREA'LIS, or northern light?*

A. The passage of *electricity* through the higher regions of the atmosphere.

Q. *Why are there DIFFERENT COLORS in the Aurora Borea'lis, such as white, yellow, red, and purple?*

A. Because the electric fluid passes through air of *different densities*. The most *rarefied air* produces a *white* light; the most *dry air*, *red*; and the most *damp* produces *yellow* streaks.

Q. *Is the Aurora Borea'lis ever accompanied by sound?*

A. Yes, it is frequently accompanied by sounds resembling hissing, murmuring, rumbling or crackling.

When its coruscations are very bright, unsettled weather generally follows; but in 1848 and 1849, brilliant displays of the Aurora Borea'lis were followed by very fine weather.

Q. *Why does a HAZE round the SUN indicate RAIN?*

A. Because the *haze* is caused by *very fine rain*, suspended in the upper regions of

*the air* : when this is the case, *a rain* of 5 or 6 *hours' duration* may be expected.

Q. *Why is a HALO round the MOON a sure indication of RAIN ?*

A. Because it is caused by *fine rain*, suspended in the *upper regions* of the air. The *larger* the halo, the *nearer the rain-clouds*, and the sooner may rain be expected.

Q. *What is the cause of a BLACK MIST : and why does it bring WET weather ?*

A. The mist is *black*, because it is *overshadowed by dense clouds* ; and *wet weather* may be expected, because the air is saturated with vapour.

Q. *Why is MIST sometimes WHITE : and why does a white mist indicate FINE weather ?*

A. The mist is *white*, because *no clouds blacken it with their shadow* ; and *fine weather* may be expected, because the sky is cloudless.

Q. *Why do we feel almost SUFFOCATED in a hot cloudy night ?*

A. Because the heat of the earth cannot escape into the upper region of

the air; but is pent-in by the clouds, and confined to the *surface of the earth*.

Q. *Why do we feel* SPRIGHTLY *in a clear bright night?*

A. Because the heat of the earth can readily escape into the upper regions of the air, and is not confined or pent-in by *thick clouds*.

Q. *Why do we feel* DEPRESSED *in SPIRITS on a WET murky DAY?*

A. 1st—Because the air is laden with vapour, and has (proportionally) *less oxygen*.

2ndly—The air being lighter than usual, *does not balance the air in our body*: and

3rdly—Moist air has a tendency to *depress the nervous system*.

Q. *What is meant by the “air balancing the air in our body?”*

A. The human body contains air of a given density; if, therefore, we ascend into *rarer air*, or descend into *denser*, the balance is destroyed, and *we feel oppressed*.

Q. *Why do we feel* UNCOMFORTABLE, *if the air*

*around is not of the SAME DENSITY, as that in our body ?*

A. Because if the air be *more dense* than our body, it will produce a feeling of *oppression* : if it be *less dense*, the air in our body will produce a feeling of *distension*.

Q. *Why do persons, who ASCEND in BALLOONS, feel PAIN in their eyes, ears, and chest ?*

A. Because the air in the upper regions of the atmosphere is *more rare* than the *air in their bodies* ; and (till *equilibrium is restored*) pain will be felt in the more sensitive parts of the body.

More especially in the tympanum of the ear.

Q. *Why do persons, who DESCEND in DIVING-BELLS, FEEL PAIN in their eyes, ears, and chest ?*

A. Because the air in the diving-bell is *compressed* by the upward pressure of the water ; in consequence of which, great pain is felt in the more sensitive parts of the body.

The pressure thus caused is sometimes sufficient to *rupture* the membrane of the tympanum, and produce incurable *deafness*.

Q. *Why are PEARL DIVERS very frequently DEAF ?*

A. Because the *pressure of the water* against the tympanum of their ears ruptures the membrane; and this rupture produces incurable deafness.

Q. *When the white cloud from the chimney of a steam engine is seen trailing a long distance; why may RAIN be expected?*

A. Because the air, is unwilling to absorb any more moisture, and must be already nearly saturated with it.

Q. *At what HOUR of the day may this prognostic of rain be most certainly depended on?*

A. When it is seen at about three in the afternoon, a wet evening is almost sure to follow.

Q. *Which is the more dense, MOIST or DRY air?*

A. *Dry* air is the densest. The weight of the atmosphere almost always *diminishes* as the fall of *rain* approaches.

Q. *When are sounds LOUDEST, in MOIST or in DRY weather?*

A. All sounds are loudest in *dry* air, because it is *densest*.

The sound of a bell can be scarcely heard, when it is rung in the receiver of an air pump. And the report of a pistol is scarcely audible on the top of a high mountain.



Q. *Why do we feel BRACED and LIGHT-HEARTED on a FINE spring or FROSTY morning?*

A. 1st—Because there is *more oxygen* in the air on a fine frosty morning, than on a wet day: and

2ndly—A brisk frosty air has a tendency to *brace* the powers of the nervous system.

Q. *Why do dogs and cats (confined to a room) feel LAZY and DROWSY, at the approach of rain?*

A. 1st—Because the air does not contain *its full proportion of oxygen*: and

2ndly—The damp *depresses the powers of their nervous system*, and makes them drowsy.

Q. *When SHEEP lie under a HEDGE, and seem unwilling to go to pasture, RAIN is at hand: Explain the reason of this.*

A. The damp air *relaxes their nervous system*, and they consequently feel listless and drowsy.

Q. *Why do HORSES neigh, CATTLE low, SHEEP bleat, and ASSES bray, at the approach of rain?*

A. Damp air *relaxes their nerves*, and, therefore, they feel languid and uneasy.

Q. *Mention some OTHER animals, which indicate the approach of rain in a similar way.*

A. When pigs squeak, as if in great pain—frogs croak with a loud hoarse noise—owls screech—woodpeckers cry—peacocks scream—guinea-fowls squall—or ducks and geese are unusually noisy, rain is close at hand.

Q. *Why do CANDLES and FIRES burn with a BLUER flame in wet weather ?*

A. Because the heat of fire is *less intense* : In consequence of which, some of the carbon is *not heated to whiteness*.

Unless the carbon be *intensely* heated, it will not unite with the oxygen to form carbonic acid, but will fly off as *smoke*.

Q. *Why do HILLS, &c. appear LARGER in WET weather ?*

A. Because the air is *laden with vapour*, which causes the rays of light to *diverge more* ; in consequence of which, they produce on the eye *larger images of objects*.

Q. *Why do TREES, &c. in WET weather appear FURTHER off, than they really are ?*

A. Because the fog or mist *diminishes the light* reflected from the object ; and as the object becomes *more dim*, it seems to be *further off*.

Q. *Why do OBJECTS sometimes seem to DANCE in warm weather, after much rain ?*

A. Because the *heat* makes the fallen rain *evaporate* again into the air very quickly, and the *ascending vapour* causes the density of the air near the ground to *vary* continually, and as the passage of the rays of light is affected, a twinkling or dancing motion is produced on the eye.

Q. *Do not DOMESTIC ANIMALS give some indications by which the approach of wet weather may be known ?*

A. It is believed that *cats* and *house dogs* feel a cutaneous irritation at the approach of rain, and offer sensible evidence of uneasiness.

Virgil and Thompson have made the subject a theme for poetry. But the imagination which makes a good poet, does not always make an accurate teacher of scientific facts.

Q. *Why is the air generally DRIER before noon and before summer, than it is after noon and after summer ?*

A. Because in the morning and in the spring, the heat of the air is on the increase, and is more capable of holding vapour suspended. In the afternoon and in the autumn it is getting on the decrease, and is less able to hold vapour suspended.

Q. *When the plants called TREFOIL, DANDELION, PIMPERNEL, &c. FOLD up their leaves, RAIN is always close at hand : Explain this.*

A. 1st—The cloudy weather diminishes the *light of the sun* ; and without the stimulus of sun-light, these flowers never open their leaves : and

2ndly—The vapour of the damp air, insinuates itself into the vessels of these delicate plants, and affects their vital sensibilities in some unknown way.

All these plants close at sun-set also.

Q. *Why do doors SWELL in RAINY weather ?*

A. Because the *air is filled with vapour*, which penetrates into the pores of the wood,—*forces the parts further apart*,—and swells the door.

Q. *Why do doors SHRINK in DRY weather ?*

A. Because *moisture is absorbed from the wood* : and, as the particles are brought closer together, the size of the door is *lessened*,—in other words, the *door shrinks*.

Q. *Why is the AIR filled with offensive SMELLS, just previous to RAIN ?*

A. Because the volatile parts which

## EFFECTS OF HEAT.

rise from dunghills, sewers, &c., are arrested by the *vapour of the air*, and prevented from *rising* so readily, as when the sun is shining brightly.

Q. *Why do FLOWERS smell SWEETER and STRONGER, just previous to RAIN?*

A. Because the volatile parts which constitute the *perfume* of flowers, are prevented (by the vapour of the air) from *rising*; in consequence of which, they are confined to the lower regions of the atmosphere.

N. B. Many essential oils and other volatile substances, which produce odours in plants, require the presence of *much moisture* for their perfect developement.

Q. *Why do HORSES and other animals stretch out their necks, and SNUFF up the AIR, just previous to a fall of RAIN?*

A. Because they smell the *odour of plants and hay*, and delight to snuff in their fragrance.

Q. *Why does SMOKE fall, when RAIN is at hand?*

A. Because the air is *less dense*, cannot buoy up the *smoke* so readily, as *dry and heavy air*.

Q. *Why do SWALLOWS FLY LOW, when RAIN is at hand?*

A. Because the *insects* (of which they are in pursuit) *have fled from the cold upper regions of the air*, to the warm air near the earth: and as their food is low, the swallows *fly low*.

Q. *Why do these INSECTS seek the lower regions of the air in WET weather, more than in FINE?*

A. Because (in wet weather) the *upper regions of the air are colder* than the *lower*; and, as insects enjoy warmth, they seek it near the earth.

Q. *Why does a DOWNWARD current of COLD AIR bring RAIN?*

A. Because it *condenses the warm vapour*; which (being condensed) descends in rain.

Hence rain generally follows a London "pea-soup" fog.

Q. *The proverb says, "A SINGLE MAGPIE in spring, FOUL WEATHER will bring." Why is this the case?*

A. Because in cold stormy weather, *one magpie alone* will leave its warm snug nest in search of food, while the other

stays with the *eggs, or young ones*; but in *fine mild* weather (when their brood will not be injured by cold) *both the magpies fly out together*.

Q. *Why is it UNLUCKY for ANGLERS to see a SINGLE magpie in spring?*

A. Because, when *magpies fly abroad singly*, the weather is cold and stormy; but, when *both-birds fly out together*, the weather is *warm and mild*, which is *favourable for fishing*.

Q. *Why do SEA-GULLS fly about the SEA in FINE weather?*

A. Because they *live upon the fishes* which are found *near the surface* of the sea in fine weather.

Q. *Why may we expect STORMY RAINS, when SEA-GULLS assemble on the land?*

A. Because the fishes (on which they live) leave the *surface* of the sea in stormy weather, and are beyond the reach of the *sea-gulls*; so they are obliged to feed on the *worms and larvæ*, which come out of the *ground* at such times.

“*Larvæ*,” little grubs and caterpillars.

Q. *Why do PETRELS fly to the SEA, during a storm ?*

A. Because they *live upon insects*, which are always to be found in abundance *about the spray of swelling waves*.

N. B. Petrels are birds of the duck-kind, which live in the open sea. They run on the top of the waves, and are called Petrels, from Petrello, an Italian word which means *Little Peter*, in illusion to St. Peter's walking on the sea to go to Jesus. Our seamen call them Mother Carey's Chickens. Their presence at sea presages a storm.

Q. *Why do CANDLES and LAMPS SPIRT, when RAIN is at hand ?*

A. Because the *air is filled with vapour* which *penetrates the wick* : where (being formed into *steam*) it expands suddenly, and produces a little explosion.

Q. *Why does a DROP of WATER sometimes ROLL along a piece of hot iron, without leaving the least trace ?*

A. Because the *bottom* of the drop is turned into *vapour*, and *buoys the drop up*, without allowing it to touch the iron.

Q. *Why does it ROLL ?*

A. Because the *current of air* (which is always passing over a heated surface) *drives it along*.



Q. *Why does a LAUNDRESS put a little SALIVA on a FLAT-IRON, to know if it be hot enough?*

A. Because, when the saliva *sticks* to the box, and is *evaporated*, she knows it is *not* sufficiently hot: but, when it *runs along the iron*, it is.

Q. *Why is the flat-iron HOTTER, if the saliva RUNS along it, than if it adheres till it is evaporated?*

A. Because, when the saliva *runs along* the iron, the heat is sufficient to *convert the bottom of the drop into vapour*; but, if the saliva *will not roll*, the iron is *not* sufficiently hot to convert the bottom of the drop into vapour.

## CHAPTER XII.

### 4.—EVAPORATION.

Q. *What is meant by EVAPORATION?*

A. The dissipation of liquid by its conversion into vapour.

Q. *What EFFECTS are produced by evaporation?*

A. The liquid vaporized *absorbs heat*

from the body whence it issues ; and the body, *deprived of the liquid by evaporation, loses heat.*

Q. *If you WET your FINGER in your mouth, and hold it up in the air, why does it feel COLD ?*

A. Because the saliva quickly *evaporates* ; and (as it evaporates) *absorbs heat from the finger*, making it feel cold.

Q. *If you BATHE your TEMPLES with ether, why does it allay INFLAMMATION and feverish heat ?*

A. Because ether very rapidly *evaporates* ; and (as it evaporates) *absorbs heat from the burning head*, producing a sensation of cold.

Q. *Why is ETHER better for this purpose, than WATER ?*

A. Because ether requires *less heat to convert it into vapour* ; in consequence of which, it evaporates more *quickly*.

N.B. Ether is converted into vapour with 98 *deg.* of heat : but water requires 212 *deg.* of heat to convert it into steam.

Q. *Why does ETHER very greatly RELIEVE a SCALD or BURN ?*

A. Because it *evaporates very rapidly* ; and (as it evaporates) *carries off the heat of the burn.*

Q. *Why do we feel COLD, when we have WET FEET or CLOTHES?*

A. Because the moisture of our shoes or clothes rapidly *evaporates*; and (as it evaporates) *absorbs heat from our body*, which makes us feel cold.

Q. *Why do WET FEET or CLOTHES give us "COLD?"*

A. Because the *evaporation absorbs heat* so abundantly from the surface of our body, that its temperature is *lowered below its natural standard*; in consequence of which, health is injured.

Q. *Why is it DANGEROUS to SLEEP in a DAMP BED?*

A. Because heat is continually absorbed from the surface of our body, to *convert the damp of the sheets into vapour*; in consequence of which, our animal heat is reduced *below the healthy standard*.

Q. *Why is HEALTH INJURED, when the temperature of the body is REDUCED below its natural standard?*

A. Because the *balance of the circulation* is destroyed: Blood is driven away from the *external surface* by the *chill*,

and thrown upon the *internal organs*, which are *oppressed* by this increased *load of blood*.

Q. *Why do we not feel the same sensation of cold, if we throw a MACINTOSH over our WET CLOTHES?*

A. Because the macintosh (being air-tight) *prevents evaporation*; and (as the *wet cannot evaporate*) no heat is absorbed from our bodies.

Q. *Why do not SAILORS "catch COLD," who are frequently wet all day with SEA-WATER?*

A. 1st—Because the *salt* of the sea *retards evaporation*; and (as the heat of their body is drawn off *gradually*) the sensation of cold is prevented: and

2ndly—The *salt* of the sea acts as a stimulant, and keeps the blood circulating in the skin.

Q. *Why does SPRINKLING a HOT ROOM with water COOL it?*

A. Because the heat of the room causes a *rapid* evaporation of the sprinkled water: and as the water evaporates, it *absorbs heat from the room*, which cools it.

Q. *Why does WATERING the STREETS and roads COOL them?*

A. Because they part with their heat, to promote the *evaporation of the water* sprinkled on them.

Q. *Why does a SHOWER of RAIN COOL the AIR in summer-time ?*

A. Because the wet earth *parts with its heat to promote evaporation* ; and when the earth is cooled, it *cools the air* also.

Q. *Why is LINEN DRIED by being exposed to the WIND ?*

A. Because the wind *accelerates evaporation*, by removing the vapour from the *surface of the wet linen*, as fast as it is formed.

Q. *Why is LINEN DRIED sooner in the open AIR, than in a confined room ?*

A. Because the particles of vapour are more rapidly removed from the surface of the linen, which increases the evaporation.

Q. *Why are WET summers generally succeeded by COLD winters ?*

A. Because the great evaporation (carried on through the wet summer) reduces the temperature of the earth *lower than usual*, and produces cold.

Q. *Why is England WARMER than it used to be, when AGUES were common?*

A. Because it is *better drained, and better cultivated.*

Q. *Why does DRAINING land promote WARMTH?*

A. Because it *diminishes evaporation*; in consequence of which, *less heat* is abstracted from the earth.

Q. *Why does CULTIVATION increase the WARMTH of a country?*

A. 1st—Because *hedges and belts of trees* are multiplied:

2ndly—The land is *better drained*: and

3rdly—The *vast forests* are cut down.

Q. *Why do HEDGES and BELTS of TREES promote WARMTH?*

A. Because they *retard evaporation*, by keeping off the *wind*.

Q. *If belts of trees promote WARMTH, why do FORESTS produce COLD?*

A. 1st—Because they *detain and condense the passing clouds*:

2ndly—They prevent the access of both *wind and sun*:

3rdly—The *soil of forests* is always

*covered with long damp grass, rotting leaves, and thick brushwood: and*

4thly—In every forest there are always many hollows *full of stagnant water.*

Q. *Why do* LONG GRASS *and* ROTTING LEAVES *promote* COLD?

A. Because they are *always damp*; and the evaporation which they promote, is *constantly absorbing heat* from the earth beneath.

Q. *Why are* France *and* Germany *warmer now, than when the vine would not ripen there?*

A. Chiefly because their *vast forests have been cut down*; and the soil is better *drained and cultivated.*

Q. *What becomes of the* WATER *of* PONDS *and* TUBS *in summer-time?*

A. Ponds and tubs are often left dry in summer-time, because their water is *evaporated by the air.*

Q. *How is this* EVAPORATION *produced and* carried on?

A. The heat of the air changes the *surface of the water into vapour*, which (blending with the air) is soon *wafted*

*away*; and this process is repeated, till the pond or tub is left quite dry.

Q. *Why are the WHEELS of some machines kept constantly WET with WATER?*

A. *To carry off (by evaporation) the heat which arises from the rapid motion of the wheels.*

Q. *Why is mould HARDENED by the SUN?*

A. Because the moisture of the mould is exhaled by *evaporation*; and, as the earthy particles are brought *closer* together, the mass becomes more solid.

Q. *Show the WISDOM of GOD in this arrangement.*

A. If the soil did not become *crusty* and *hard in dry weather*, the heat and drought would *penetrate the soil*, and kill both seeds and roots.

Q. *Why is TEA cooled FASTER in a SAUCER than in a cup?*

A. Because *evaporation is increased by increasing the surface*; and, as tea in a saucer presents a *larger surface to the*



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*ir*, its heat is more rapidly carried off by evaporation.

The subject of "convection" will be treated of in a future chapter : it would scarcely be understood in this place. See p. 238.

Q. *Why is not the* VAPOUR *of the* SEA SALT ?

A. Because the salt of the sea-water is always *left behind*, in the process of evaporation.

Q. *What is that* WHITE CRUST, *which appears (in hot weather) upon* CLOTHES *wetted by* sea-water ?

A. Dry salt, left on the clothes after the water has evaporated.

Q. *Why does this* WHITE CRUST *always* DIS-APPEAR *in* WET *weather ?*

A. Because the *moisture of the air dissolves the salt ;* in consequence of which, it is no longer visible.

Q. *Why should* NOT *persons, who take violent exercise, wear very* THICK CLOTHING ?

A. Because it prevents perspiration from evaporating. When the heat of the body is increased by exercise, *perspiration reduces it again (by evaporation) to a healthystandard :* as thick clothing *prevents* this evaporation, it is injurious to health.

## CHAPTER XIII.

## COMMUNICATION OF HEAT.

## 1.—CONDUCTION.

Q. *How is heat COMMUNICATED from one body to another?*

A. 1.—By Conduction. 2.—By Absorption. 3.—By Reflection. 4.—By Radiation. And 5.—By Convection.

Q. *What is meant by CONDUCTION of heat?*

A. Heat communicated from one body to another by *actual contact*.

Q. *Why does not a PIECE of WOOD (blazing at ONE end) feel HOT at the OTHER?*

A. Because *wood is so bad a conductor*, that heat does not traverse freely through it: hence, though one end of a stick be blazing, the other end may be quite cold.

Q. *Why do some things feel COLDER, than others?*

A. Principally because they are *better*

*conductors* ; and draw off heat from our body much faster.

Q. *What are the BEST conductors of heat ?*

A. *Dense solid bodies*, such as metal and stone.

Q. *Which metals are the most RAPID CONDUCTORS of heat ?*

A. The *best* conductors of heat are 1—gold, 2—silver, 3—copper :

The *next* best are, 4—plat'inum, 5—iron, 6—zinc, 7—tin : Lead is a very *inferior* conductor to any of the preceding metals.

Q. *What are the worst conductors of heat ?*

A. All *light* and *porous* bodies ; such as hair, fur, wool, charcoal, and so on.

Two of the *worst* conductors known are hare's fur and eider down ;—the two next worst are beaver's fur and raw silk ;—then wood and lamp-black ;—then cotton and fine lint ;—then charcoal, wood ashes, &c.

Q. *Why are cooking vessels often furnished with WOODEN HANDLES ?*

A. Because wood is *not* a *good* conductor, like metal ; and, therefore, *wooden* handles prevent the heat of the vessel from rushing into our hands, to burn them.

Q. *Why is the HANDLE of a METAL TEAPOT made of WOOD?*

A. Because wood is a *bad conductor*; therefore, the heat of boiling water is *not so quickly conveyed* to our hand by a wooden handle, as by one made of metal.

Q. *Why would a metal handle BURN the HAND of the tea-maker?*

A. Because metal is an *excellent conductor*; therefore, the heat of boiling water would *pass so quickly* into the *metal handle*, as to burn the hand.

Q. *Prove that a metal handle would be HOTTER, than a WOODEN one.*

A. If we *touch the metal collar* into which a wooden handle is fixed, we shall find that the wooden handle *feels cold*, but the metal collar *intensely hot*.

Q. *Why do persons use paper or woollen KETTLE-HOLDERS?*

A. Because paper and woollen are both very *bad conductors of heat*; in consequence of which, the heat of the kettle does *not readily pass through them* to the hand.

Q. Does the heat of a boiling kettle NEVER get through the woollen or paper kettle-holder?

A. Yes; but though the kettle-holder became as hot as the kettle itself, it would never *feel* so hot.

Q. Why would not the kettle-holder FEEL so hot as the kettle, when both are of the same temperature?

A. Because it is a very *bad* conductor, and disposes of its heat *too slowly* to be perceptible; but metal (being an *excellent* conductor) disposes of its heat *so quickly*, that the sudden influx is painful.

Q. Why does HOT METAL feel MORE *intensely warm*, than HOT WOOL?

A. Because metal gives out a much *greater quantity of heat* in the same space of time; and the *influx* of heat is, consequently, *more perceptible*.

Q. Why does MONEY in our pocket feel very HOT, when we stand before a FIRE?

A. Because metal is an excellent conductor, and becomes rapidly heated: For the same reason, it becomes *rapidly cold*, whenever it comes in contact with a substance *colder than itself*.

Q. *Why does a PUMP-HANDLE feel intensely COLD in WINTER?*

A. Because it is an *excellent* conductor, and draws off heat from the hand so rapidly, that the sudden loss produces a sensation of intense coldness.

Q. *Is the IRON handle of the pump really COLDER, than the WOODEN pump itself?*

A. No; every inanimate substance (exposed to the same temperature) possesses in reality the *same* degree of *heat*.

Q. *Why does the IRON handle seem so MUCH COLDER, than the WOODEN pump?*

A. Merely because *iron* is a *better conductor*; and, therefore, *draws off heat* from the hand more rapidly than wood.

Q. *Why does a STONE or marble HEARTH feel to the feet COLDER, than a carpet or hearth-rug?*

A. Because *stone* and *marble* are *good* conductors; but *woollen carpets* and *hearth-rugs* are very *bad* conductors.

Q. *How does the STONE hearth make our feet COLD?*

A. As soon as the hearth-stone has

absorbed a portion of heat from our foot, it instantly disposes of it, and calls for a *fresh supply*; till the hearth-stone has become of the *same temperature*, as the foot placed upon it.

Q. *Do not the woollen CARPET and HEARTH-RUG conduct heat from the human body?*

A. Yes; but being very *bad* conductors, they convey heat away so *slowly*, that its loss is scarcely perceptible.

Q. *Is the COLD HEARTH-STONE in reality of the SAME temperature, as the WARM CARPET?*

A. Yes; every thing in the room is really of *one temperature*; but some things *feel* colder than others, because they are *better conductors*.

Q. *How LONG will a hearth-stone feel cold to the feet resting on it?*

A. Till the *feet* and the *hearth-stone* are both of the *same temperature*; and then the sensation of cold in the hearth-stone will go off.

Q. *Why would not the HEARTH-STONE feel COLD, when it is of the SAME temperature as our feet?*

A. Because heat would no longer

*pass from our feet into the hearth-stone, in order to produce equilibrium.*

Q. *Why does a HEARTH-STONE (when the fire is lighted) feel HOTTER than the HEARTH-RUG ?*

A. Because the hearth-stone is an *excellent conductor*, and part with its heat *very readily* ; but the woollen hearth-rug (being a *bad conductor*) parts with its heat *very reluctantly*.

Q. *Why does parting with heat RAPIDLY make a HEARTH-STONE feel WARM ?*

A. Because the rapid influx of heat raises the temperature of our body so *suddenly*, that we cannot *help perceiving the increase*.

Q. *Why does the non-conducting power of a HEARTH-RUG prevent its feeling so HOT, as it really is ?*

A. Because it parts with its heat so *slowly and gradually*, that we scarcely *perceive* its transmission into our feet.

Q. *When we plunge our HANDS into a basin of WATER, why does it produce a sensation of cold ?*

A. Because water is a *better conductor* than air ; and, as it draws off heat from our hands *more rapidly*, it feels colder.



Q. *Why does the CONDUCTING power of water make it feel COLDER, than AIR?*

A. Because it *abstracts heat from our hands so rapidly*, that we feel its loss; but the air abstracts heat so *very slowly*, that its gradual loss is hardly perceptible.

Q. *Is water a GOOD conductor of heat?*

A. No; liquids are generally *bad* conductors of heat; but yet water is a *much better* conductor than air.

Quicksilver, which is a fluid, is a good conductor of heat, because it is *metallic*.

Q. *Why is WATER a BETTER conductor of heat, than AIR?*

A. Because it is *more dense*: The conducting power of any substance depends upon its *solidity*, or the *closeness of its particles*.

Q. *How do you know, that WATER is NOT a GOOD conductor of heat?*

A. Because it may be made to *boil at its surface*, without imparting sufficient heat to *melt ice a short distance below the surface*.

Q. *Why are not liquids GOOD conductors of heat?*

A. Because the heat (which should be transmitted) *produces evaporation*, and *flies off* in the vapour.

Q. *Why does a POKER (resting on a fender) feel COLDER than the HEARTH-RUG, which is further off the fire?*

A. Because the poker is an *excellent conductor*, and draws heat from our hand much *more rapidly* than the woollen hearth-rug, which is a *very bad conductor*: though both, therefore, are *equally warm*, the *poker* seems to be the *colder*. (See also, p. 193.)

Q. *Why are HOT BRICKS (wrapped in cloth) employed in cold weather to keep the feet warm?*

A. Because bricks are *bad conductors* of heat, and cloth or flannel *still worse*: in consequence of which, a hot brick, (wrapped in flannel) will *retain its heat a very long time*.

Q. *Why is a tin pan (filled with HOT WATER) employed as a FOOT WARMER?*

A. Because *polished tin* (being a bad radiator of heat) *keeps hot a very long time*; and warms the feet resting upon it.

Q. *What is meant by being a "bad RADIATOR of heat?"*

A. To radiate heat is to throw off heat *by rays*, as the sun; a polished tin pan does not throw off the heat of boiling water from its surface, but keeps it in.

Q. *Why are tin foot-warmers covered with FLANNEL?*

Q. *What disadvantage would it be, if the POLISH of the tin were injured?*

A. If the tin foot-warmer were to lose its polish, it would get cold in a *much shorter time*.

Q. *Why would a tin foot-warmer get COLD SOONER, if its POLISH were INJURED?*

A. Because *polished* tin throws off heat *very slowly*; but dull, scratched, painted, or dirty tin, *throws off heat very quickly*.

Q. *Why are furnaces and stoves (where much HEAT is required) built of POROUS BRICKS?*

A. Because bricks are bad conductors, and prevent the escape of heat; in consequence of which, they are employed where great heat is required.

Q. *Why are FURNACE DOORS, &c. frequently covered with a \_\_\_\_\_ and SAND?*

A. Because \_\_\_\_\_ is a very bad

an excellent conductor, and rapidly communicates heat to the air around.

Q. *Why does the Bible say, that God "giveth SNOW like WOOL?"*

A. Because snow (being a very bad conductor of heat) protects vegetables and seeds from the frost and cold.

Q. *How does the non-conducting power of SNOW PROTECT VEGETABLES from the frost and cold?*

A. It prevents the heat of the earth from being drawn off by the cold air, which rests upon it.

Q. *Why are WOOLLENS and FURS used for clothing in cold weather?*

A. Because they are *very bad conductors* of heat: and, therefore, prevent the warmth of our body from being *drawn off* by the cold air.

Q. *Do not woollens and furs actually IMPART heat to the body?*

A. No; they merely prevent the heat of the body from *escaping*.

Q. *Where would the heat ESCAPE to, if our body were NOT wrapped in wool or fur?*

A. Into the air; for cold air (coming in contact with our body), would gradually *draw away its heat*, till both were of the same temperature.

Q. *What is the principal USE of CLOTHING in winter-time?*

A. 1st—To prevent animal heat from escaping too freely: and

2ndly—To protect our body from the *external air* (or wind), which would carry away its heat too rapidly.

Q. *Why are beasts covered with FUR, HAIR, or WOOL?*

A. Because fur, hair, and wool, are *very slow conductors* of heat:—

dumb animals cannot be clad, like human beings) God has given them a robe of hair or wool, to keep them warm.

Q. *Why are birds covered with DOWN or FEATHERS?*

A. Because down and feathers are *very bad* conductors of heat; and (as birds cannot be clad, like human beings) God has given them a robe of feathers, to keep them warm.

Q. *Show how the goodness of God is manifested, even in the clothing of BIRDS and BEASTS.*

A. Small birds, which are the most *delicate*, have a *thicker* covering of feathers, than those which are larger and more hardy; and beasts which live in the cold regions of the frigid zones have *thicker, coarser, and warmer* coats, than those which dwell in the tropical heat.

Q. *Why are FURS, HAIR, and FEATHERS, such SLOW conductors of heat?*

A. Because a great quantity of *air* lurks entangled between their fibres; and *air* is a *very bad* conductor of heat.

The warmest clothing is that which fits the body very *loosely* in every part except at the *extremities*: because more hot air will be confined by a *loose* garment, than by one which fits the body *tightly*.

Q. *If AIR be a BAD conductor of heat, why should we not feel as warm WITHOUT clothing, as when wrapped in wool and fur?*

A. Because the air is *never at rest*; and every fresh particle which comes in contact with our body, carries off a fresh portion of heat.

Q. *Does the AIR, which surrounds a naked body, become (by contact) as WARM as the BODY itself?*

A. It would do so if it remained *motionless*; but, as it remains only a *very short time*, it absorbs as much heat as it can in the time, and passes on.

Q. *Why do we feel COLDER in WINDY WEATHER, than in a CALM day?*

A. Because the particles of air pass over us *more rapidly*; and every fresh particle takes from us *some* portion of heat.

This effect will be greatly influenced by the temperature of the wind.

Q. *Show the wisdom of God in making AIR a BAD conductor.*

A. If air were a *good conductor* (like iron and stone) heat would be drawn so *rapidly* from our body, that we should be *chilled to death*. Similar evils would be

felt also by *all* the animal and vegetable world.

Q. Does HOT air give heat as slowly to our body, as COLD air takes it away?

A. Yes. A man may go into air of the temperature of  $300^{\circ}$ , without having the heat of his body raised more than two or three degrees.

Workmen enter ovens, in the manufacture of moulds of plaster of Paris, in which the thermometer stands  $100^{\circ}$  higher than the temperature of boiling water, and take no harm. The precaution must be taken, to have no metal in contact with the person; a gentleman who once entered a hot air oven with spectacles on, was severely burnt; the metal frame became rapidly heated, being a good conductor, and communicated the heat to his nose.

Q. Could as high a temperature be borne, when the AIR is in MOTION?

A. No. The effect of the heated air becomes more *intense* when it is in *motion*, because *fresh* portions are then continually applied to the surface of our body.

Q. Can all bodies be touched without inconvenience, when their temperature is as high as  $300^{\circ}$ ?

A. No. Metals cause pain when their temperature is  $120^{\circ}$ ; water scalds when its temperature is  $150^{\circ}$ .

Q. Why does FANNING one's face in summer make it COOL?



A. Because the fan *puts the air in motion*, and makes it pass more *rapidly over one's face*; and (as the temperature of the *air* is always *lower* than that of the human *face*) each puff of air *carries off* some portion of its heat.

Q. Does FANNING make the air itself cooler?

A. No: fanning makes the *air hotter and hotter*.

Q. How does FANNING one's face increase the HEAT of the air?

A. By driving the air more rapidly over the human body; and causing it to *absorb more heat*.

Q. If fanning makes the air HOTTER, why can it make a person feel COOLER?

A. Because it takes heat *out of the face*, and gives it to the *air*.

Q. Why is broth COOLED by BLOWING it?

A. Because the breath causes a rapid *change of air* to pass over the broth; and (as the air is colder than the broth) it continually *absorbs heat* from it, and makes it cooler and cooler.

Q. Would not the air absorb heat from broth just as well WITHOUT BLOWING?

A. No; *air is a very bad conductor*; unless, therefore, the *change be rapid*, that portion of air nearest the surface of the broth would soon become *as hot as the broth itself*.

Q. *Would not hot air* PART *with its heat instantly to the* CIRCUMJACENT *air?*

A. No; not instantly. Air is so bad a conductor, that it parts with its heat *very slowly*: unless, therefore, it be kept in *continual* motion, it would cool the broth *very slowly* indeed.

Q. *Why does* WIND *generally feel* COOL?

A. Because it drives the air more rapidly over our body; and this rapid *change of air*, draws off a large quantity of heat.

Q. *Why does* air *absorb heat more* QUICKLY *by being set in* MOTION?

A. Because every fresh portion of air *absorbs a fresh amount of heat*; and the more rapid the *current of air*, the greater will be the quantity of heat absorbed.

Q. *If the air were hotter than our body, would the* WIND *feel* COOL?

A. No; if the air were *hotter* than our body, it would feel insufferably warm.

Q. *Why would the air feel unpleasantly HOT, if it were WARMER than our BODY?*

A. Because it would *add* to the heat of our body, instead of *diminishing* it.

Q. *Is the OPEN AIR ever as HOT as the human body?*

A. Not in *this* country: in the hottest summer's day, the air is at least 10 or 12 degrees *cooler* than the human body.

Q. *Is the EARTH a good conductor of heat?*

A. No; the earth is a *bad* conductor of heat.

Q. *Why is the earth a BAD conductor of heat?*

A. Because its particles are not *continuous*: The power of *conducting* heat depends upon the *continuity of matter*.

Q. *Why is the earth (BELOW the surface) WARMER in winter, than the surface itself?*

A. Because the earth is a *bad* conductor of heat; and, therefore, (although the ground be frozen) the frost never penetrates more than a *few inches below the surface*.

Q. *Why is the earth (BELOW the surface) COOLER in summer, than the surface itself?*

A. Because the earth is a *bad* conductor of heat; and, therefore (although the *surface be scorched* with the burning sun), the intense heat cannot penetrate to the *roots* of the plants and trees.

Q. *Show the WISDOM of GOD in making the EARTH a BAD conductor.*

A. If the *heat and cold* could penetrate the earth (as freely as the heat of a fire penetrates iron) the springs would be dried up in summer, and frozen in winter; and all vegetation would be soon destroyed.

Q. *Why is water from a SPRING always COOL, even in summer?*

A. Because the earth is so *bad* a conductor, that the rays of the sun can penetrate only a few inches below the surface; in consequence of which, the *springs* of water are *not affected* by the heat of summer.

Q. *Why is it COOL under a SHADY tree, in a hot summer's day?*

A. 1st—Because the overhanging foliage *screens off* the rays of the sun:

2ndly—As the rays of the sun are

warded off, the *air* (beneath the tree) is not heated by the *reflection* of the earth : and

3rdly—The leaves of trees are good radiators of heat ; and, therefore, send *back* to the earth a great deal of that which they receive.

Dew forms upon leaves early in the evening, because the air cools down quickly by rapid radiation. (See p. 210, &c.)

Q. *Why do Laplanders wear SKINS, with the FUR INWARDS ?*

A. 1st—Because *dry skins* prevent the *wind* from penetrating to their body ; and

2ndly—The *air* (between the hairs of the fur) soon becomes *heated* by the heat of the body ; in consequence of which, the Laplander in his fur is clad in a case of *hot air*, impervious to cold and wind.

Q. *Why does a LINEN shirt feel COLDER than a COTTON one ?*

A. Because *linen* is a *much better conductor* than cotton ; and, therefore, draws away animal heat *more rapidly*, and produces a greater sensation of cold.

Q. *Does fine or coarse WOOLLEN cloth make the WARMEST clothing ?*

A. The *finer* the cloth, the more

slowly it conducts heat. Fine cloths, therefore, are warmer than coarse ones.

Q. *Is SILK a good conductor of heat ?*

A. No ; it is a bad conductor of heat. Spun silk allows the heat of the body to pass off more quickly than wool ; but raw silk confines it more than wool (*p.* 172).

Count Rumford found that when a thermometer cooled down 135° in air in 575 seconds, it did not cool down to the same extent in less than 917 seconds, when surrounded by *spun* silk ; in 1046 seconds, when surrounded by cotton wool ; in 1118 seconds, when surrounded by sheep's wool ; in 1284 seconds, when surrounded by raw silk ; and in 1305 seconds, when surrounded by eider down.

Q. *Why is our FACE COOLED by wiping the temples with a fine cambric handkerchief ?*

A. Because the fine fibres of the cambric have a strong capillary attraction for *moisture*, and are excellent *conductors* of heat : in consequence of which, the moisture and heat are *abstracted* from our face by the cambric, and a sensation of coolness produced.

"Capillary attraction," i. e. *the attraction of a thread or hair*. The wick of a candle is wet with grease, because the melted tallow runs up the cotton from capillary attraction.

Q. *Why would not a COTTON handkerchief do as well ?*

A. Because the coarse fibres of cotton

have very little capillary attraction, and are *very bad* conductors: in consequence of which, the heat of our face would be *increased* (rather than *diminished*) by the use of a *cotton* handkerchief.

## CHAPTER XIV.

### 2.—ABSORPTION OF HEAT.

Q. *What is the difference between CONDUCTING heat, and ABSORBING heat?*

A. To *conduct* heat, is to *transmit* it from one body to another through a *conducting* medium: To *absorb* heat, is to *suck it up*, as a sponge sucks up water.

Q. *Give me an example.*

A. *Black cloth absorbs*, but does not *conduct heat*: thus, if black cloth be laid in the sun, it will *absorb the rays* very rapidly; but if *one end* of the black cloth be made hot, it would not *conduct* the heat to the other end.

Q. *Are good CONDUCTORS of heat, good ABSORBERS also?*

A. No; every *good conductor* of heat is a *bad absorber* of it: and no *good absorber* of heat can be a *good conductor* also.

Q. *Is IRON a good ABSORBER of heat?*

A. No; *iron* is a *good conductor*, but a *very bad absorber* of heat.

The power of absorbing heat depends on the nature of the surface of a body; thus, bright or polished surfaces will not absorb heat so readily as rough and black ones.

Q. *Why do the FIRE-IRONS (which lie upon a FENDER) remain COLD, although they are before a good fire?*

A. Because they are *bad absorbers* of heat; in consequence of which, they remain *cold*, unless they come in *contact* with the stove or fire.

Q. *Why are the FIRE-IRONS intensely HOT, when they rest AGAINST a STOVE which contains a good fire?*

A. Because they are *excellent conductors* of heat, and draw it rapidly from the stove with which they are in contact.

Q. *Why does a KETTLE boil faster, when the bottom and back are covered with SOOT?*

A. Because the black soot *absorbs heat* very quickly from the fire, and the metal *conducts* it to the water.



Q. *Why will not a NEW KETTLE boil so fast as an OLD one ?*

A. Because the *bottom and sides* of a new kettle are *clean and bright* : but in an *old* kettle they are *covered with soot*.

Q. *Why would a KETTLE BOIL more SLOWLY, if the bottom and back were clean and bright ?*

A. Because *bright* metal does *not absorb heat*, but *reflects it* : and (as the heat is *thrown off* from the surface of *bright* metal by reflection), therefore, a new kettle takes a longer time to boil.

Reflects heat, i.e. throws it off.

Q. *Why do we wear a BLACK outer DRESS, if we want to be warm ?*

A. Because a *black outer dress* quickly *absorbs heat* from the sun's rays.

Q. *Why do persons WEAR WHITE dresses in SUMMER time ?*

A. Because white *throws off the heat* of the sun by reflection, and is a very bad absorbent of heat ; in consequence of which, white dresses never become so *hot from the scorching sun*, as dark colours do.

Q. *Why do NOT persons wear WHITE dresses in WINTER time ?*

A. Because white will *not absorb heat*, like black and other dark colours; and therefore, *white dresses are not so warm as dark ones.*

Q. *What COLOURS are WARMEST for dresses?*

A. For *outside* garments *black* is the warmest, and then such colours as approach nearest to black (as dark blue and green). *White* is the *coldest* colour for external clothing.

Q. *Why are DARK colours (for external wear) so much WARMER than LIGHT ones?*

A. Because *dark colours absorb heat* from the sun more abundantly than *light ones.*

Q. *How can you prove that DARK colours are WARMER than LIGHT ones?*

A. If a piece of *black* and a piece of *white* cloth were laid upon snow, in a few hours the *black cloth* will have *melted the snow beneath*; whereas, the *white cloth* will have produced little or *no effect upon it at all.*

N.B. The *darker* any colour is, the *warmer* it is, because it is a better absorbent of heat. • The order may be thus arranged:—  
1. Black (warmest of all).—2. Violet.—3. Indigo.—4. Blue.—  
5. Green.—6. Red.—7. Yellow; and 8. White (coldest of all).

Q. *Why are* BLACK KID GLOVES *unpleasantly* HOT *for summer wear?*

A. 1st—Because *black* absorbs the solar heat: and

2ndly—*Kid* will not allow the heat of our hand to *escape through the glove*.

Q. *Why are* LISLE THREAD GLOVES *agreeably* COOL *for summer wear?*

A. 1st—Because thread absorbs *perspiration*: and

2ndly—It *conducts away* the heat of our hot hands.

Q. *Are* Lisle thread gloves ABSORBENTS of heat?

A. No; Lisle thread gloves are generally of a *grey or lilac colour*; and, therefore, *do not absorb solar heat*.

Q. *Why is a* PLATE-WARMER *made of* UN-PAINTED *bright* TIN?

A. Because bright tin *reflects the heat* (which issues from the fire in rays) upon the meat; and, therefore, greatly assists the process of roasting.

*Reflects the heat, i. e. throws it back upon the meat.*

Q. *Why would not the* tin REFLECTOR *do as well, if it were* PAINTED?

A. Because it would then *absorb* heat,

and *not reflect it so well*. A plate-warmer should never be *painted*, but be kept *very clean, bright, and free from all scratches*.

Q. *Why should a REFLECTOR be kept so very CLEAN, and free from all SCRATCHES?*

A. Because, if a reflector were *spotted, dull, or scratched*, it would *absorb* heat, instead of *reflecting* it; and, consequently, would be of no use whatsoever as a *reflector*.

Q. *Why does HOAR-FROST remain on TOMB-STONES, long after it has melted from the grass and gravel-walks of a church-yard?*

A. Because tomb-stones (being *white*) will *not absorb heat*, like the darker grass and gravel; in consequence of which, they remain too *cold* to thaw the frost congealed upon their surface.

Q. *If black absorbs heat, why have those who live in HOT climates BLACK skins, and not WHITE skins, which would not absorb heat at all?*

A. Because *black* will not *blister* from the heat of the sun. Although, therefore, the black skin of a negro *absorbs heat* more plentifully than the *white skin of a*

*European ; yet the blackness prevents the sun from blistering or scorching it.*

Q. *How is it known, that BLACK colour prevents the sun from either BLISTERING or SCORCHING the skin ?*

A. *If you place a white cloth glove over one hand, and a black cloth one on the other, (when the sun is burning hot), the hand with the white cloth covering will be scorched, but not the other.*

Q. *WHICH hand will FEEL the HOTTER ?*

A. *The hand covered with black cloth will feel the hotter, but will not be scorched by the sun : whereas, the hand covered with white cloth (though much cooler) will be severely scorched.*

Q. *Why does the BLACK skin of a NEGRO never SCORCH or BLISTER with the hot sun ?*

A. *Because the black colour absorbs the heat, and conveys it below the surface of the skin.*

Q. *Why does the WHITE European skin BLISTER and SCORCH, when exposed to the hot sun ?*

A. *Because white will not absorb heat ; and, therefore, the hot sun rests on the surface of the skin, and scorches it.*

Q. *Why has a negro BLACK EYES?*

A. Because the black colour defends them from the strong light of the tropical sun. If a negro's eyes were not black, the sun would so *dazzle them*, that the negro might become blind.

Q. *Why is WATER (in hot weather) kept COOLER in a BRIGHT TIN POT than in an earthen one?*

A. Because bright metal will *not absorb* heat from the hot air, like an *earthen* vessel; in consequence of which, the water is kept *cooler*.

Boiling water is also kept *hot* in bright metal, better than in earthen vessels. See p. 209.

## CHAPTER XV.

### 3.—REFLECTION OF HEAT.

Q. *What is meant by REFLECTING heat?*

A. To reflect heat, is *to throw it back in rays* from the surface of the reflecting body, towards the place whence it came.

Q. *What are the BEST reflectors of heat?*

A. All *bright* surfaces, and *light* colours.

Q. *Are good* ABSORBERS *of heat good* REFLECTORS *also?*

A. No; those things which *absorb* heat *best*, *reflect* heat *worst*; and those which *reflect* heat *worst*, *absorb* it *best*.

Q. *Why are those things which* ABSORB *heat, unable to* REFLECT *it?*

A. Because the same heat cannot be both *absorbed* and *reflected*; if absorbed or taken *into* a substance, it cannot also be *thrown off* from its surface; and if *thrown off* from the surface, it cannot also be taken *into* the substance.

Q. *Why are* REFLECTORS *always made of* LIGHT-COLOURED *and highly-*POLISHED METAL?

A. Because *light-coloured* and *highly-polished metal* makes the best of all reflectors.

Q. *Why do not plate-warmers blister and scorch the* WOOD *behind?*

A. Because the bright tin front throws the heat of the fire *back again*, and will not allow it to penetrate to the wood behind.

Q. *If metal be such an excellent CONDUCTOR of heat, how can it REFLECT heat, or throw it off?*

A. Polished metal is a *conductor of heat*, only when that heat is communicated by *actual contact*: But, whenever heat falls upon bright metal in *rays*, it is *reflected back* again, and the metal remains cool.

Q. *What is meant by "heat falling upon metal in RAYS," and not "by contact?"*

A. A piece of metal thrust into a fire, would be in *actual contact with that fire*; but if *held before a fire*, the heat of the fire would fall upon it in *rays*.

Q. *What is the use of the TIN SCREEN or reflector, used in ROASTING?*

A. It throws the heat of the fire *back upon the meat*: and, therefore, both assists the process of *roasting*, and helps to *keep the kitchen cool*.

Q. *How does a tin reflector tend to keep the KITCHEN COOL?*

A. By *confining the heat* of the fire to the *hearth*, and preventing its dispersion throughout the kitchen.

Q. *Why are SHOES HOTTER for being DUSTY?*



A. Because dull dusty shoes will *absorb heat* from the sun, earth, and air; but shoes brightly polished, *throw off* the heat of the sun by reflection.

Q. *Why does it always FREEZE on the TOP of a HIGH mountain?*

A. 1st—Because air is heated by *contact with the earth's surface*, and not by solar rays which pass *through* it: As a mountain-top affords very small surface for such contact, it remains intensely cold: and

2ndly—When air flows up the side of a mountain, it *expands* from diminished pressure; and consequently absorbs heat from surrounding objects.

Rarefied air can hold more latent heat than dense air can.

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## CHAPTER XVI.

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### 4.—RADIATION.

Q. *What is meant by RADIATION?*

A. Radiation means *the emission of rays*: Thus, the sun radiates both light

and heat; that is, it emits *rays of light and heat* in all directions.

Q. WHEN is heat RADIATED from one body to another?

A. When the two bodies are *separated* by a *non-conducting medium*: thus, the sun radiates heat towards the earth, because the *air* (which is a very bad conductor) *comes between*.

Q. On WHAT does radiation depend?

A. On the *roughness* of the radiating surface: thus, if metal be *scratched*, its radiating power is increased: because the *heat has more points to escape from*.

Q. Does a FIRE radiate heat?

A. Yes; and because *burning fuel emits rays of heat*, therefore, we *feel warm* when we stand before a fire.

Q. Why does our FACE feel *uncomfortably HOT*, when we approach a FIRE?

A. Because the fire radiates heat upon it; and (not being covered) it feels the effect immediately.

Q. Why does the fire catch our FACE more than it does the REST of our body?

A. Because the *rest* of our body is

*covered* with clothing; which (being a *bad* conductor) prevents the same sudden and rapid transmission of heat to our skin.

Q. *Do those substances which RADIATE heat, ABSORB heat also?*

A. Yes. Those substances which *radiate most*, also *absorb most heat*: and those which *radiate least*, also *absorb the least heat*.

Q. *Does any thing ELSE radiate heat, besides the SUN and FIRE?*

A. Yes: *all things radiate heat in some measure, but not equally well.*

Q. *WHAT things RADIATE heat the NEXT BEST to the sun and fire?*

A. All *dull and dark* substances are *good radiators* of heat; but all *light and polished* substances are *bad radiators*.

Q. *Why should the FLUES (connected with Arnott's stoves, &c.) be always blackened with BLACK LEAD?*

A. In order that the heat of the flue may be more readily *diffused* throughout the room. Black lead radiates heat more freely, than any other known substance.

A better name for black lead is "graphite," because it contains no metallic lead, but is a mixture of *carbon and iron*. It is used chiefly in black-lead pencils; and hence its name, from the Greek word *γραφειν* to write. The black lead used for domestic purposes contains only a small portion of true "graphite."

Q. *Why does a POLISHED metal tea-pot make BETTER tea, than a black earthen one?*

A. Because polished metal (being a very bad radiator of heat) keeps the water hot much longer; and the hotter the water is, the better it "draws" the tea.

Q. *Why will not a DULL black tea-pot make good tea?*

A. Because the heat of the water flies off so quickly through the dull black surface of the tea-pot, that the water is very rapidly cooled, and cannot "draw" the tea.

Q. *Why do pensioners, and aged cottagers, generally prefer the little black EARTHEN tea-pot to the bright METAL one?*

A. Because they set it on the hob "to draw;" in which case, the little black tea-pot will make the best tea.

Q. *Why will a BLACK tea-pot make better tea than a bright metal one, if set upon the HOB to DRAW?*

A. Because the black tea-pot will

absorb *heat plentifully* from the fire, and keep the water *hot*: whereas, a bright *metal* tea-pot (set upon the hob) would *throw off* heat by *reflection*.

Q. *Then sometimes a BLACK EARTHEN tea-pot is the best, and sometimes a bright metal one.*

A. Yes; when a tea-pot is *set on the hob "to draw,"* black *earth* is the *best*, because it *absorbs heat*: But, when a tea-pot is *not* set on the hob, bright *metal* is the *best*; because it *radiates heat very slowly*, and therefore *keeps the water hot*.

Q. *Why does a SAUCEPAN, which has been USED, boil in a shorter time than a NEW one?*

A. Because the bottom and back are *covered with soot*; and *black soot* rapidly *absorbs heat* from glowing coals.

Q. *Why should the FRONT and LID of a SAUCEPAN be clean and bright?*

A. Because they cannot *absorb heat*, as they do not come in contact with the fire; and (being bright) they will not suffer the heat inside them to *escape* by radiation.

Q. *In what state should a saucepan be, in order that it may BOIL most QUICKLY?*

A. All those parts, which come in contact *with the fire*, should be covered with *soot*, in order to absorb heat; but all the *rest* should be as *bright* as possible to prevent the *escape* of heat by radiation.

Q. *Why is it said that "SATURDAY'S KETTLE boils the FASTEST?"*

A. Because, on Saturday, the *front* and *top* of the kettle are generally *cleaned* and *polished*; but the *bottom* and *back* of the kettle are *never* cleaned.

Q. *Why should NOT the BOTTOM and BACK of a kettle be clean and polished?*

A. Because, *they come in contact with the fire*, and (while they are covered with black soot) *absorb heat freely* from the burning coals.

Q. *Why should the FRONT and TOP of a kettle be clean and well polished?*

A. Because polished metal *will not radiate heat*; and, therefore, (while the front and top of a kettle are well polished) *the heat is kept in*, and not suffered to escape by radiation.

Q. *Why does the BOTTOM of a kettle feel nearly cold, when the water is boiling HOT?*

A. Because black soot is a very *bad conductor of heat*; and, therefore, the heat of the boiling water is some time before it gets *through the soot*, which adheres to the bottom of the kettle.

Q. *Why is the LID of a KETTLE intensely HOT, when the water boils?*

A. Because the bright metal lid is an *admirable conductor*; and, therefore, *heat from the boiling water pours into our hand* the moment we touch it.

Q. *Show the benefit of SMOKE in COOKING.*

A. The carbon of the fuel (which flies off in smoke) naturally *blackens* all culinary vessels set upon a fire to boil, and thus renders them fit for use.

“Culinary vessels” are vessels used in kitchens for cooking, as saucepans, boilers, kettles, &c., from the Latin word “Culi’na,” (*a kitchen.*)

Q. *How does SMOKE make culinary vessels FIT for USE?*

A. By covering them with soot. If it were not for the soot (which gathers round a kettle or saucepan) heat would *not be absorbed*, and the process of boiling would be greatly retarded.

Q. *Why is boiling water kept HOT in a bright METAL pot better than in an earthen vessel?*

A. Because bright metal (being a *bad radiator*) will not *throw off* from its surface the heat of the boiling water.

Q. *Why would not a metal pot serve to keep water hot if it were DULL and DIRTY?*

A. Because it is the bright *polish* of the metal, which makes it a bad radiator: and if it were *dull, scratched, or dirty*, heat would *escape* very rapidly.

Water in hot weather is also kept *cooler* in bright metal than in *dull* or earthen vessels. See p. 199.

Q. *Why are dinner-covers made of BRIGHT TIN or SILVER?*

A. Because light-coloured and highly-polished metal is a *very bad radiator of heat*; and, therefore, bright tin or silver will not allow the heat of the cooked food to *escape through the cover by radiation*.

Q. *Why should a MEAT-COVER be very brightly POLISHED?*

A. To prevent the heat of the food from escaping by *radiation*. If a meat-cover be *dull* or *scratched*, it will *allow the heat of the food beneath* to fly off into the room.



Q. *Why should a SILVER meat cover be PLAIN, and not enchased ?*

A. Because a *chased* meat-cover would not prevent the radiation of heat, so perfectly as a plain one.

Q. *What is DEW ?*

A. Dew is the *vapour* of the air *condensed*, by coming in contact with bodies *colder* than itself.

Q. *Why is the GROUND sometimes COVERED with DEW ?*

A. Because the surface of the earth (at sunset) is made so *cold* by radiation, that the warm vapour of the air is chilled, by contact, and condensed into dew.

Q. *Why is the earth COLDER than the AIR, after the sun has set ?*

A. Because the earth *radiates* heat very freely, but the air does not; in consequence of which, the earth is often 5 or 10 degrees colder than the air (after sunset); although it was much *warmer* than the air, during the whole day.

Q. *Why is the earth WARMER than the AIR, during the day ?*

A. Because the earth *absorbs* solar heat very freely, but the air does not; in

consequence of which, it is often many degrees warmer than the air, during the day.

Q. *Why is the surface of the ground COLDER in a FINE clear night, than in a CLOUDY one?*

A. Because, on a fine clear star-light night, heat *radiates* from the earth *freely*, and is lost in open space: but on a *dull* night, the clouds *arrest* the process of *radiation*.

Q. *Why is DEW deposited only on a FINE clear NIGHT?*

A. Because the *surface* of the ground *radiates* heat most freely on a fine night; and (being cooled down by this loss of heat) *condenses* the vapour of the *air* into *dew*.

Q. *Why is there NO DEW on a dull CLOUDY night?*

A. Because clouds *arrest* the radiation of *heat* from the earth; and (as the heat cannot freely escape) the earth's surface is not sufficiently cooled down, *to condense* the vapour of the *air* into *dew*.

Q. *Why is a cloudy night WARMER than a fine one?*

A. Because clouds *prevent the radiation of heat* from the *earth*; in consequence of which, the surface of the earth remains *warmer*.

Q. *Why is DEW most abundant in situations most EXPOSED?*

A. Because the radiation of heat *is not arrested* by houses, trees, hedges, or any other things.

Q. *Why is there scarcely any DEW under a TREE when in full foliage?*

A. 1st—Because the thick foliage *arrests the radiation of heat* from the earth: and

2ndly—It radiates some of its own heat *towards the earth*; in consequence of which, the ground underneath a leafy tree is not sufficiently cooled down, to chill the vapour of the air into dew.

Q. *Why is there never much DEW at the foot of WALLS and HEDGES?*

A. 1st—Because they act as screens, *to arrest the radiation of heat* from the earth: and

2ndly—They themselves *radiate some portion of heat* towards the earth; in

consequence of which, the ground at the foot of walls and hedges is not sufficiently cooled down, to condense the vapour of the air into dew.

Q. *Why is there little or NO DEW beneath a FLOWER-AWNING, although that awning be open on all four sides ?*

A. 1st—Because the awning arrests the radiation of heat from the ground beneath: and

2ndly—It radiates some of its own heat downwards; in consequence of which, the ground beneath an awning is not sufficiently cooled down, to chill the vapour of air into dew.

Q. *How can a thin covering of BASS or even MUSLIN, protect trees from FROST ?*

A. Because any covering prevents the radiation of heat from the tree; and if trees are not cooled down by radiation, the vapour of the air will not be frozen, as it comes in contact with them.

Bass, pronounce bas—a kind of matting used by gardeners.

Q. *Why is the BASS or CANVASS itself (which covers a tree) always drenched with DEW ?*

A. Because it radiates heat both up-

*wards and downwards; in consequence of which, it is so cooled down; that it readily condenses the vapour of the air into dew.*

Q. *Why does SNOW (at the foot of a HEDGE or WALL) melt sooner than that in an open field?*

A. Because hedges or walls *radiate heat into the snow*, which melt it.

Q. *Why is there NO DEW after a WINDY NIGHT?*

A. Because wind *evaporates the moisture*, as fast as it is deposited.

Q. *Why are VALLEYS and HOLLOWS often thickly covered with DEW, although they are sheltered?*

A. Because surrounding hills prevent the *repose* of air from being *disturbed*; but do not *overhang* and *screen* the valleys sufficiently to *arrest* radiation.

Q. *Why does DEW fall more abundantly on SOME things, than on others?*

A. Because some things radiate heat *more freely* than others; and, therefore, become *much cooler* in the night.

Q. *Why are things which radiate heat most*

FREELY, *always the most* THICKLY COVERED *with* DEW?

A. Because the vapour of the air is *condensed into dew*, the moment it comes in contact with them.

Q. WHAT *kind of things radiate heat most* FREELY?

A. Grass, wood, and the leaves of plants, radiate heat *very freely*: but polished metal, smooth stones, and woollen cloth, part with their heat *very tardily*.

Q. *Do the leaves of ALL plants radiate heat* EQUALLY *well*?

A. No. Rough *woolly leaves* (like those of a holly-hock) radiate heat much *more freely*, than the *hard smooth polished leaves* of a common laurel.

Q. *Shew the WISDOM of GOD in making grass, the leaves of trees, and ALL VEGETABLES, excellent radiators of heat.*

A. As vegetables *require much moisture*, and would often *perish* without a plentiful deposit of dew, God wisely made them to *radiate heat freely*, so as to *condense the vapour* (which touches them) *into dew*.

Q. *Will polished METAL, smooth STONES, and woollen CLOTH, readily collect DEW ?*

A. No. While grass and the leaves of plants are completely *drenched with dew*, a piece of *polished metal*, or of *woollen cloth* (lying on the same spot), will be *almost dry*.

Q. *Why would polished METAL and woollen CLOTH be DRY, while grass and leaves are drenched with DEW ?*

A. Because polished metal and woollen cloth *part with their heat so slowly*, that the vapour of the air is *not condensed into dew*, when it passes over them.

Q. *Why is a gravel walk almost DRY, when a grass plat is thickly covered with DEW ?*

A. Because *grass is a good radiator*, and throws off its heat very *freely*; but *gravel is a bad radiator*, and parts with its heat slowly.

Q. *Is that the reason why GRASS is saturated with DEW, and the GRAVEL is NOT ?*

A. Yes. When the vapour of warm air comes in contact with the *cold grass*, it is instantly deposited as dew; but it is *not so freely condensed*, as it passes over the warmer gravel.

Q. *Why is DEW rarely distilled upon hard rocks and barren lands ?*

A. Because rocks and barren lands are so *compact* and *hard*, that they can neither absorb nor radiate *much heat*; and (as their temperature varies *very little*) very little *dew* distils upon them.

Q. *Why does DEW fall more abundantly on cultivated soils than on barren lands ?*

A. Because cultivated soils (being *loose* and *porous*, very freely radiate by night, the heat which they absorbed by day; in consequence of which, they are much *cooled* down, and plentifully *condense* the vapour of the passing air into *dew*.

Q. *Show the WISDOM of GOD in this arrangement.*

A. Every plant and each portion of land, which *needs* the moisture of dew, is adapted to *collect* it; but *not a single drop* is *wasted*, where its refreshing moisture is *not required*.

Q. *Shew the WISDOM of GOD in making polished metal and woollen cloth BAD RADIATORS of heat.*

A. If polished metal collected dew as



easily as grass, it could never be kept *dry*, and *free from rust*. Again, if woollen garments collected dew as readily as the leaves of trees, we should be often *wet*, and subject to the risk of "taking cold."

Q. *Show how this affords a beautiful illustration of GIDEON'S MIRACLE, recorded in the book of Judges, vi. 37, 38.*

A. The *fleece of wool* (which is a very *bad* radiator of heat) was *wet* with dew; when the *grass* (which is a most excellent radiator) was quite *dry*.

Q. *Was not this CONTRARY to the laws of nature?*

A. Yes; and was, therefore, a plain demonstration of the *power of God*, who could thus change the very *nature* of things at his will.

Q. *Why do our CLOTHES feel DAMP, after walking in a fine evening in SPRING or AUTUMN?*

A. Because vapour (condensed by the cooling of the air) is deposited upon them, like dew.

Q. *Why are WINDOWS often covered with thick MIST, and the frames wet with standing WATER?*

A. Because the temperature of the

*external air* always falls at sunset, and chills the *window-glass* with which it comes in contact.

Q. *How does this account for the MIST and WATER on a window?*

A. As the warm vapour of the room touches the *cold glass*, it is *chilled* and *condensed* into *mist*; and the mist (collecting into drops) rolls down the window-frame in little streams of water.

Q. *Why does the GLASS of a window COOL down more rapidly, than the AIR of the room itself?*

A. Because the air of the room is kept warm by fires, and animal heat; in consequence of which, it suffers very little diminution of heat from the setting of the sun.

Q. *Whence arises the VAPOUR of a room?*

A. 1st—The *air* of the room itself naturally contains *vapour*:

2ndly—The *breath* and *insensible perspiration* of the inmates increase this vapour: and

3rdly—*Hot dinners*, the *steam of tea*, and so on, increase it still more.

Q. *What is meant by "INSENSIBLE perspiration?"*

A. From every part of the human body, an *insensible* and *invisible perspiration* issues all night and day; not only in the hot weather of *summer*, but also in the coldest day of *winter*.

Q. *If the perspiration be both INSENSIBLE and INVISIBLE, how is it known that there is any such perspiration?*

A. If you put your naked arm into a clean dry *glass tube*, the *perspiration* will *condense* on the glass, like mist.

Q. *Why are carriage windows very soon covered with thick MIST?*

A. Because the warm vapour of the carriage is *condensed* by the *cold glass*, and covers it with a thick mist.

Q. *Why is the glass window COLD enough to condense the vapour of the carriage?*

A. Because the *inside* of the carriage is much *warmer* than the *outside*; and the glass window is made cold by contact with the *external air*.

Q. *Where does the WARM vapour of the carriage come from?*

A. From the warm *breath* and

insensible *perspiration* of the persons riding in it.

Q. *What is the cause of the pretty FROST WORK, seen on bed-room windows in winter-time?*

A. The *breath* and insensible *perspiration* of the sleeper (coming in contact with the ice-cold window) are *frozen* by the cold glass; and form those beautiful appearances seen in bed-rooms on a winter's morning.

Q. *Why is the GLASS of a window colder than the WALLS of a room?*

A. Because glass is so *excellent a radiator*, that it parts with its heat more *rapidly* than the walls do.

Q. *Why is a TUMBLER of cold WATER made quite DULL with mist, when brought into a room full of people?*

A. Because the *hot vapour* of the room is *condensed* upon the cold tumbler, with which it comes in contact; and is changed from the invisible and gaseous form, into that of a *thick mist*.

Q. *Why is a GLASS made quite DULL, by laying a hot hand upon it?*

A. Because the perspiration from the hot hand is *condensed* upon the cold glass, and made perceptible.

Q. *Why are WINE-GLASSES made quite DULL, when brought into a room full of company?*

A. Because the *hot vapour* of the room (coming in contact with the cold wine-glasses) is condensed upon them, and covers them with moisture, like dew.

Q. *Why does this misty appearance GO OFF, after a little time?*

A. Because the glass becomes of the same *temperature*, as the *air* of the room; and will no longer *chill* the *vapour* which touches it, and *condense* it into *mist*.

Q. *Why is a WINE-GLASS (which has been brought out of a cellar into the AIR) covered with a thick MIST in summer time?*

A. Because the vapour of the hot air is *condensed* into a thick mist, by contact with the cold glass.

Q. *Why does BREATHING on a glass make it quite dull?*

A. Because the vapour of the hot breath is *condensed* by the cold glass, and covers it with a thick mist.

Q. *Why are the walls of a house covered with WET in a sudden THAW?*

A. Because they are thick, and cannot *change* their *temperature* so fast as the air; in consequence of which, they *retain* their *cold*, after the thaw has set in.

Q. *How does "RETAINING their COLD" account for their being so WET?*

A. As the vapour of the warm air touches the *cold walls*, it is chilled and *condensed* into *water*; which either *sticks* to the walls, or trickles down in little streams.

Q. *Why does a thick WELL-BUILT house contract more DAMP of this kind, than an ORDINARY one?*

A. Because its walls are much thicker; and (if the frost has penetrated far into the *bricks*) they will be some time before they are reduced to the same *temperature* as the *air*.

Q. *Why are BALUSTERS, &c., DAMP after a THAW?*

A. Because they are made of some very close-grained varnished wood, which cannot *change* its *temperature*, so fast as the *air*.

and (being made much *colder* than the air) *chills* the *passing vapour*, and condenses it into dew.

Q. *Does not AIR radiate heat, as well as the EARTH and its various plants?*

A. No; the air never *radiates heat*; nor is it made *hot* by the *rays* of the *sun*.

Q. *How is the air made HOT or COLD?*

A. By convection of *hot* or *cold* currents.

Q. *Explain this.*

A. Air which is heated by contact with the earth's surface ascends, and colder comes into its place, to be in its turn heated in the same way; this process is repeated, until there no longer remains any cold air to be made warm.

Q. *How is the air made COLD?*

A. By direct contact with the colder earth, and by being mixed with colder currents that are brought by the wind.

Q. *Why is MEAT very subject to TAINT, if exposed on a clear moon-light night?*

A. Because on a *clear night* it will radiate heat very freely; and,

quently, be *wet* with dew, which favours *rapid* putrefaction.

Q. *How do MOON-LIGHT nights conduce to the rapid growth of plants?*

A. Radiation is carried on very rapidly on bright moon-light nights; in consequence of which, *dew* is very plentifully *deposited* on young plants, which conduces much to their growth and vigour.

Q. *Why is evening dew INJURIOUS to health?*

A. Because it is always laden with *noxious exhalations* from the *earth*; especially in *marshy* countries.

Q. *Is HONEY-DEW a similar thing to dew?*

A. No. Honey-dew is a sweet liquid, shed by a very small *insect* (called the *a'phis*), and deposited in autumn on the under surface of favourite leaves.

Frequently on Lime Trees, in the Spring also.

Q. *Does honey-dew INJURE leaves, or do them good?*

A. It injures them very much, by filling the *pores* with a thick clammy liquid; in consequence of which, the leaf can neither *transpire*, nor needful food.



Q. *What EFFECT has honey-dew upon the appearance of a leaf?*

A. After a little time, the leaf (being *smothered and starved*) begins to turn of a *dingy yellow colour*.

Q. *Are not ANTS very fond of honey-dew?*

A. Yes; and crawl up to the loftiest trees, in order to obtain it.

Q. *What is the cause of MIST (or earth-fog)?*

A. If the *night* has been very *calm*, radiation of heat from the earth has been very abundant; in consequence of which, the *air* (resting on the earth) has been *chilled*, and its vapour condensed into a thick *mist*.

Q. *Why does not the MIST become DEW?*

A. Because the chill of the air is so rapid, that vapour is condensed *faster* than it can be *deposited*; and (covering the earth in a mist) prevents any further *radiation of heat*.

Q. *When the earth can no longer radiate heat upwards, does it continue to CONDENSE the vapour of the air?*

A. No; the air (in contact with the earth) becomes about equal in *temperature*

with the surface of the earth itself; for which reason, the mist is not *condensed* into *dew*, but remains *floating* above the earth as a thick cloud.

Q. *This mist seems to rise higher and higher, and yet remains quite as dense below as at first. Explain the cause of this.*

A. The air resting on the earth is first chilled, and slowly mixing with the air above, condenses it also into mist likewise: and as layer is thus added to layer, the mist seems to be *rising*, when (in fact) it is only *deepening*.

Q. *Why does mist and dew VANISH, as the SUN rises?*

A. Because the air becomes *warmer* after sun-rise, and *absorbs* the vapour.

Q. *Why is a DEW-DROP ROUND?*

A. Because every part of it is *equally balanced*; and, therefore, there is no cause why *one part* of the drop should be further from the centre, than *another*.

Q. *Why is the dew-drop (on a broad leaf) sometimes FLATTENED?*

A. Because two or more drops of dew roll together, and make one large *spheroid* (or flattened drop.)

Q. *Why will dew-drops ROLL about cabbage plants, poppies, &c., without wetting the surface ?*

A. Because the leaves of cabbages and poppies are covered with a very *fine waxen powder*, over which the dew-drop rolls without wetting the surface, as a drop of rain over dust.

Q. *Why does not a drop of rain WET the DUST over which it rolls ?*

A. Because dust has no *affinity* for water : and, therefore, repels it.

Q. *Why does not a dew-drop WET the POWDER of cabbage-plants ?*

A. Because the fine powder, which covers cabbage-leaves has no *affinity* for water ; and, therefore, repels it.

Q. *Why will dew-drops ROLL over a ROSE, &c. without wetting the petals ?*

A. Because the leaves of a rose contain an *essential oil*, which has no *affinity* for water ; and, therefore, repels it.

Q. *Why can SWANS and DUCKS dive under water without being WETTED ?*

A. Because their feathers are covered with an *oily secretion*, which has no *affinity* for water ; and, therefore, repels it.

Q. *Why are currents of air from the land COLDER than those blowing over water?*

A. Because the earth radiates heat after sun-set more freely than water; consequently, *air* which comes in contact with the land is colder than that which comes in contact with water.

For other questions respecting land and sea breezes, see Chapter XXII. page 300.

Q. *Why is not air, which passes over water, so COOL as that which passes over land?*

A. Because *water* does not cool down at sun-set, so fast as *land* does: and, therefore, the air in contact with it remains warmer.

Q. *Why does not WATER cool down so fast as LAND?*

A. 1st—Because the *surface* of water is perpetually *changing*; and, as fast as one surface is made cold, *another* is presented: and

2ndly—When water is made cold it *sinks*, and *warmer* portions of water *rise* to occupy its place: before, therefore, the *surface* of water is *cooled*, the *whole volume* must be made cold; which is *not* the case with land.

Q. *What is the cause of a "pea-soup" LONDON FOG?*

A. These fogs (which occur generally in the winter time) are occasioned thus:—Some current of air (being suddenly cooled) *descends* into the *warm streets*, forcing back the smoke in a *mass* towards the earth.

Q. *Why are there not ALWAYS fogs, every night?*

A. Because the air will always hold in solution a certain quantity of vapour, (which varies according to its temperature): and, when the air is not *saturated*, it may be cooled without parting with its vapour.

Q. *When do fogs occur at night?*

A. When the air is *saturated with vapour* during the day. When this is the case, it deposits some of its superabundant moisture in the form of dew or fog, as soon as its capacity for holding vapour is lessened by the *cold night*.

Q. *Why is there very often a fog over MARSHES and RIVERS, at night-time?*

A. Because the air of marshes is

almost always near *saturation*; and, therefore, the least depression of *temperature* will compel it to relinquish some of its moisture in the form of dew or fog.

Q. *What is the DIFFERENCE between dew and rain?*

A. In *dew*, the condensation is made near the *earth's surface*.

In *rain*, the drops falls from a considerable height.

Q. *What is the CAUSE of both dew and rain?*

A. Cold *condensing* the vapour of the *air*, when near the point of *saturation*.

Q. *Why do mist and fog VANISH at sun-rise?*

A. Because the condensed particles are again *changed* into *invisible* vapour by the heat of the sun.

Q. *What is the difference between a MIST and a FOG?*

A. MIST is generally applied to *vapours* condensed on *marshes, rivers, and lakes*.

Fog is generally applied to *vapours*

surface, unless the night has been very clear indeed.

Q. *Why does hoar-frost very often cover the GROUND and TREES, when the water of rivers is not frozen ?*

A. Because it is not the effect of cold in the *air*, but cold on the surface of the *earth* (produced by excessive radiation), which *freezes dew* into hoar-frost.

Q. *Why is the hoar-frost upon GRASS and VEGETABLES much thicker than that upon lofty trees ?*

A. Because the air (resting on the *surface* of the ground) is much colder after sun-set, than the air *higher up*: in consequence of which, more *vapour* is *condensed* and *frozen* there.

Q. *Why is the AIR (resting on the surface of the earth) colder than that in the HIGHER regions ?*

A. Because the *earth* radiates more heat than the *leaves* of lofty trees ; and therefore, more *rapidly condenses* and *freezes* the vapour of the air.

Q. *Why are evergreens often FROST-BITTEN, when lofty trees are NOT ?*

A. Because they do not rise far above

the surface of the earth ; and (as the air *contiguous* to the earth is made *colder* by radiation, than that in the *higher* regions) therefore, the *low evergreen* is often *frost-bitten*, when the lofty tree is uninjured.

Q. *Why is there little or no hoar-frost, under SHRUBS and shady TREES ?*

A. 1st—Because the leafy top *arrests* the process of radiation from the earth :

2ndly—Shrubs and trees radiate *heat* towards the earth ; and, therefore, the *ground beneath* is never *cold enough* to *congeal* the little dew deposited there.

Q. *Why is there more HOAR-FROST along the shady margin of a HEDGE than in the open field, as the day advances ?*

A. 1st—Because the shade of the hedge prevents the dissipation of the *hoar-frost* by the *sun* : and

2ndly—Because the hedge screens off wind and prevents the *repose of the air* being disturbed.

Q. *What is the cause of that hoar-frost, which arises from FROZEN FOG ?*

A. The congelation of night-fog by



## CONVECTION.

the freezing chill of *early* morning, in consequence of which the fog is frozen upon every object on which it was deposited.

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## CHAPTER XVII.

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### 5.—CONVECTION.

Q. *What is meant by the CONVECTION of heat ?*

A. Heat communicated by being *carried* to another thing or place; as the hot water rising from the *bottom* of a kettle, carries heat upward in its ascent. (*see p. 252.*)

Q. *Are liquids good CONDUCTORS of heat ?*

A. No; liquids are *bad conductors*; and are, therefore, made hot by *convection*.

Q. *Why are liquids BAD conductors of heat ?*

A. Because their particles (upon every change of temperature) are put into *motion*, and do not remain sufficiently long in contact with each other to conduct heat progressively, like a bar of iron.

When heat is applied to the surface of a fluid, it is very *slowly* diffused in a downward direction, because the warmed particles continually ascend, without having time to impart heat to the particles below.

Q. *Explain how water is made HOT.*

A. The water *nearest the fire* is *first* heated, and (being heated) *rises* to the *top*; its place is supplied by *colder* portions, which are heated in turn, and this interchange continues till *all* the water is boiling hot.

Q. *Why is water in such continual FERMENT, when it is BOILING?*

A. This commotion is mainly produced by the *ascending* and *descending* currents of hot and cold water.

The escape of steam from the water contributes to increase this agitation.

Q. *How do these two currents PASS each other?*

A. The hot *ascending* current rises up through the *centre* of the mass of water; while the cold *descending* currents pass down by the metal sides of the kettle.

For other questions upon the subject of boiling water, see from page 115 to 222.

Q. *Why is heat applied to the BOTTOM, and not to the top of a kettle?*

A. Because the heated water always *ascends* to the *surface*; if therefore, heat

were applied to the *top* of a vessel, the water *below the surface* would never be heated.

Q. *As the lower part of a grate is made RED-HOT by the fire above, why would not water boil, if fire were applied to the TOP of a kettle?*

A. The iron of a grate is an excellent conductor; if, therefore, one part be heated, the heat is conducted to every other part: But *water* is a very *bad conductor*, and will not diffuse heat in a similar way.

Q. *Prove that water is a BAD conductor of heat.*

A. When a blacksmith immerses his red-hot iron in a tank of water, the water which surrounds the iron is made *boiling hot*, while that *below the surface* remains quite cold.

Q. *If you wish to COOL liquids, where should the cold be applied?*

A. To the *top* of the liquid; because the *cold* portions will always *descend*, and allow the warmer parts to come in contact with the cooling substance.

Q. *Does BOILING water get hotter by being KEPT on the fire?*

A. No :—not if the steam be suffered to escape.

Q. WHY does not boiling water get HOTTER, if the steam be suffered to escape ?

A. Because the water is converted into steam, as fast as it boils ; and the steam carries away the additional heat.

Q. Why does SOUP keep hot longer than boiling water ?

A. Because the grease and various ingredients floating in the soup, retard the ascent of the hot particles, and prevent their rising so freely to the surface.

Q. If you want to keep water HOT for a long time, how could it be done ?

A. By adding a little starch or flour to the water.

Q. Why would a little STARCH, added to boiling water, serve to keep it hot ?

A. Because it would retard the ascent of the hot particles, and prevent their reaching the surface of the water.

Q. Why do thick milk, rice milk, &c. remain HOT longer than water ?

A. Because the ascent of the

particles is opposed by the flour or rice, which therefore cannot reach the surface so quickly.

Q. *Is STEAM visible or invisible?*

A. Steam is *invisible*; but when it comes in contact with the air, and is *condensed* into small drops, it becomes visible.

Q. *How do you know that steam is INVISIBLE?*

A. If you look at the spout of a boiling kettle, you will find that the steam (which issues from the spout) is always invisible for about *half an inch*; after which, it becomes *visible*.

Q. *WHY is the steam invisible for half an inch?*

A. Because the air is not able to condense it, as it first issues from the spout; but when it *spreads* and comes in contact with a larger volume of air, the *invisible steam* is readily condensed into *visible drops*.

Q. *WHY do steam-engines sometimes burst?*

A. Because steam is very *elastic*; and this elasticity increases in a greater proportion than the heat which produces it: unless, therefore, some *vent* be freely

allowed, steam will burst the vessel which confines it.

Q. *Is air a good CONDUCTOR?*

A. No; *air* is a very *bad conductor*; and is heated (like water) by *convection*.

Q. *How is a room warmed by a STOVE?*

A. The air *nearest* the fire is made hot *first*, and rises; *cold air* then *descends*, is heated, and *ascends* in like manner; and this interchange goes on, till *all* the air of the room is *warmed*.

Q. *Why are fires placed on the FLOOR of a room?*

A. Because heated air always *ascends*. If, therefore, the fire were not *near the floor*, the air of the *lower* part of the room would never be heated by the fire at all.

Q. *If you take a poker out of a fire, and hold the hot end DOWNWARDS: why is your hand scorched with heat?*

A. Because the hot end of the poker *heats the air* around it; and this hot air (in its ascent) *scorches* our hand.

Q. *How should a RED-HOT poker be carried, so as not to burn our fingers?*

A. With the hot end *upwards*; for then the air (heated by the poker) would not pass over our hand and scorch it.

## PART II.

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### AIR.

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#### CHAPTER XVII.

Q. *Of what is atmospheric AIR composed?*

A. Principally of two gases, *oxygen* and *nitrogen*; mixed together in the following proportion: viz. 1 gallon of oxygen, to four of nitrogen.

It must not be forgotten, that the air contains small quantities of other gaseous substances also, as *vapour of water, carbonic acid, and ammonia.*

Q. *What do you mean by a GAS?*

A. A permanent *elastic* fluid, resembling air.

N. B. MOST GASES ARE INVISIBLE AND TRANSPARENT, LIKE AIR.

"PERMANENT."—In this respect gas differs from *vapour*, which is *not* permanent; for vapour may be easily condensed by cold into a *liquid*, but gas does not change its gaseous form under ordinary pressures.

"ELASTIC."—In this respect gas differs from a *liquid*, which is almost inelastic; whereas gas is exceedingly elastic.

"RESEMBLING AIR" or aeriform.—The word "Gas" means *air*, but air is a compound of two gases. Some few gases are visible, as *CHLORINE*, which is a greenish yellow.

Q. *What is the difference between a GAS and a LIQUID?*

A. Gases are *elastic*, but liquids *not*.

Q. *Illustrate what is meant by "the ELASTICITY of gas."*

A. If from a vessel full of gas, *half* were taken out—the *other* half would immediately spread itself out, and fill the same space, as was occupied by the original quantity.

Q. *Prove that a liquid is NOT ELASTIC.*

A. If from a gallon of water you take *half*, the remaining 4 pints will take up only *half* the room, that the whole gallon previously did: a *liquid*, therefore, is not elastic, like *gas*.

Strictly speaking, a liquid is *slightly* elastic; inasmuch as it may be *compressed*, and will afterwards recover its former dimensions.

Q. *What are the chief uses of the OXYGEN of the air?*

A. To *support* combustion, and *sustain* life.

Q. *What is meant, when it is said, that the oxygen of the air "SUPPORTS COMBUSTION"?*

A. It means *this*: It is the *oxygen* of the air, which makes *fuel burn*.



Q. *How does the OXYGEN of the air make FUEL BURN?*

A. The fuel is decomposed (by heat) into *hydrogen* and *carbon*; and these elements, combining with the *oxygen* of the air, produce combustion.

Q. *What GAS is produced by the combination of carbon and oxygen?*

A. CARBONIC ACID GAS. (See p. 38.)

Q. *What becomes of the HYDROGEN of the FUEL?*

A. The *hydrogen* of the fuel combines with the *oxygen* of the air, and forms WATERY VAPOUR; but the combination is attended by the production of *flame*, owing to the very inflammable nature of hydrogen.

It must be remembered, that the gas of burning fuel is *not pure*, but *carburetted hydrogen*.

Q. *What becomes of the NITROGEN of the air, amidst all these changes and combinations?*

A. The nitrogen escapes *unchanged*, to be again mixed with *oxygen*, and converted into common AIR.

Q. *What is meant, when it is said, that oxygen "SUSTAINS LIFE"?*

A. It means this: If a person could not inhale oxygen, he would die.

Q. *What GOOD does this inspiration of oxygen do?*

A. 1st—It gives *vitality* to the *blood*:  
and

2ndly—Is the *cause* of *animal heat*.

Q. *How is food converted into BLOOD?*

A. After it is swallowed, it is dissolved in the stomach into a *grey pulp*, called CHYME; it then passes into the intestines, and is converted by the “bile” into a *milky substance*, called CHYLE.

Chyme, pronounce kyme—chyle, pronounce kyle—each as one syllable.

Q. *What BECOMES of the milky substance called CHYLE?*

A. It is absorbed by the vessels called “*lacteals*,” and poured into the veins on the *left side* of the *neck*.

“Lacteals,” pronounce lac'-te-als.

Q. *What becomes of the chyle, AFTER it is poured into the veins?*

A. It *mingles* with the *blood*, and is itself *converted* into blood also.

Q. *How does the oxygen we inhale, MINGLE with the blood?*

A. The oxygen of the air *mingles* with the blood in the *lungs*, and converts it into a *bright red colour*.

Q. *What colour is the blood BEFORE it is oxidized in the lungs?*

A. *A dark purple. The oxygen turns it to a bright red.*

Oxidized, i. e. impregnated with oxygen.

Q. *Why are persons so PALE, who live in close rooms and cities?*

A. Because the air in close rooms and cities is not *fresh*; and being *deficient* in *oxygen*, cannot turn the blood to a beautiful bright red.

Q. *Why are persons, who live in the open air and in the country, of a RUDDY complexion?*

A. Because they inhale fresh air, which has its full proportion of oxygen: and the blood derives its bright red colour from the *oxygen* of the air inhaled.

Q. *Why is not the air in CITIES so FRESH, as that in the COUNTRY?*

A. Because it is impregnated with the *breath* of its numerous inhabitants, the *odour* of its sewers, the *smoke* of its fires, and many other impurities.

Q. *How does oxygen convert the colour of blood into a bright RED?*

A. The *colouring* matter of the blood

is formed of very minute *globules*, floating in it; the oxygen (uniting with the *coats* of these *globules*) makes them *milky*—and the dark colouring matter of the blood (seen through this *milky coat*) appears of a *bright red*.

EXP.: If you put some dark *venous* blood into a *milky glass*, and hold it up towards the light, it will appear of a *bright florid* colour, like *arterial* blood.

Q. *How does the combination of oxygen with the blood produce animal HEAT?*

A. The principal element of the blood is *carbon*; and this carbon (combining with the oxygen of air inhaled) produces *carbonic acid gas*, in the same way as burning fuel. (*see p. 39.*)

Q. *What becomes of the NITROGEN of the air, after the oxygen enters the blood?*

A. It is thrown out from the lungs unchanged, by the act of breathing; to be again mixed with *oxygen*, and converted into common AIR.

Q. *Why does the vitiated air (after the oxygen has been absorbed) COME OUT of the MOUTH, and not sink into the stomach?*

A. Because it is driven out by the

contraction of the walls of the chest, and there is no vacant space in the cavity of the gullet and stomach for it to fall into.

N. B. The lungs are a *hollow spongy mass*, capable of holding air, and of being *dilated*. They are so situated in the thorax (or chest), that the air *must* enter into them, whenever the cavities of the thorax are enlarged. The process of breathing is performed thus: When we *INHALE*, the thorax (or chest) is expanded; in consequence of which, a *vacuum is formed round the lungs*, and heavy external air instantly enters (through the mouth and throat) *to supply* this vacuum.

When we *EXHALE*, the thorax *contracts* again; in consequence of which, it can no longer contain the *same quantity* of air, as it did before; and some of it is necessarily *expelled*. When this expulsion of air takes place, the *muscular fibres*, which form the floor of the chest, *contract*, in order to assist the process.

Q. *If (both in combustion and respiration) the OXYGEN of the air is CONSUMED, and the NITROGEN REJECTED—Why are not the PROPORTIONS of the air DESTROYED?*

A. Because the *under surface of vegetable leaves* (during the day) gives out *oxygen*; and thus restores to the air the very element of which it has been deprived.

Q. *Whence do leaves OBTAIN the oxygen, which they exhale?*

A. From the *carbonic acid*, absorbed by the *roots* from the soil, and carried to the leaves by the rising *sap*.

N. B. Carbonic acid (it must be remembered) is a compound of carbon and oxygen.

Q. *How do plants contrive to absorb carbonic acid from the soil?*

A. It rises (by capillary attraction) through the small fibrous roots, after it has been dissolved in the soil by water.

Q. *Whence does the SOIL obtain carbonic acid?*

A. 1st—From the air; from which it is driven by falling showers:

2ndly—From the decomposition of vegetable and animal matters, which always produces this gas in abundance: and

3rdly—All lime-stone, chalk, and calcareous stones, contain vast quantities of carbonic acid in a *solid* state, and the presence of any acid sets it free.

Calcareous, i. e. of a limy nature.

Q. *If leaves throw off the OXYGEN of the carbonic acid, what becomes of the carbon?*

A. It is retained to give *firmness* and *solidity* to the plant itself.

Q. *Show how God has made ANIMAL life dependent on that of VEGETABLES.*

A. *Animals* require *oxygen* to keep them alive, and *draw* it from the air by inspiration: The under surface of *leaves*

*gives out oxygen*; and thus supplies the air with the *very gas* required for the use of animals.

Q. *Show how God has made* VEGETABLE *life dependent on that of animals.*

A. Plants require *carbonic acid*, which is their *principal food*; and all animals exhale this gas from their lungs. Thus *animals* supply plants with *carbonic acid*, and plants supply animals with *oxygen*.

Q. *How is air* HEATED?

A. By “convective currents.”

Q. *Explain what is meant by* “CONVECTIVE CURRENTS.”

A. When a portion of air is heated, it *rises upwards in a current*, carrying heat with it: other *colder air succeeds*, and (being *heated* in a similar way) *ascends* also: and these are called “convective currents.”

. “Convective currents”—so called from the Latin words, *cum-vectus* (carried with); because the *heat* is “carried with” the current.

Q. *Is air heated by the rays of the* SUN?

A. No; air is *not heated* (in any sensible degree) by the action of the *sun's rays* passing through it.

Q. *Why is the air HOTTER on a SUNNY day, than on a CLOUDY one?*

A. Because the sun heats the *surface* of the *earth*, and the air (resting on the earth) is *heated by contact*: as soon as it is heated it *ascends*, and its place is supplied by *colder* portions, which are heated in turn also.

Q. *If air be a BAD conductor, why does hot iron become cold, by exposure to the AIR?*

A. Because it is made cold—1st—By “convection;” and 2ndly—By “radiation.”

Q. *How is hot iron made cold by CONVECTION?*

A. The air resting on the hot iron (being intensely heated) rapidly ascends with the heat it has absorbed; *colder* air succeeding *absorbs more heat*, and ascends also; and this process is repeated, till the hot iron is completely *cooled down*.

Q. *How is hot iron cooled by RADIATION?*

A. While its heat is being carried off by “convection,” the hot iron *throws off heat* (on <sup>on</sup> all sides) *by radiation* also.



Q. *What is meant by* RADIATION?

A. The throwing off of heat (in all directions) from the surface of a hot body.

*Radiation.*—It was once thought that heat was emitted from hot bodies in the form of rays.

Q. *How is soup COOLED by being left exposed to the* AIR?

A. It throws off *some* heat by *radiation*; but it is mainly cooled down by *convection*.

Q. *How is hot soup cooled down by* CONVECTION?

A. The air *resting* on the *hot soup* (being heated) *ascends*; *colder* air *succeeding* *absorbs more heat*, and *ascends also*; and this process is repeated, till the soup is made *cool*.

The particles on the surface of the broth *sink* as they are cooled down, and *warmer* particles rise to the surface; which greatly assists the cooling process.

Q. *Why are hot tea and soups COOLED the faster for being* STIRRED about?

A. 1st—Because agitation assists in bringing the hottest particles to the *surface*:

2ndly—The action of stirring *agitates* the air, and brings it more *quickly* to the soup or tea: and

3rdly—As the hotter particles are more rapidly brought into contact with the air, convection is *more rapid*.

Blowing tea or broth cools it also. (*See p. 186.*)

Q *If a shutter be closed in the day-time, the stream of light (piercing through the crevice) seems in CONSTANT agitation. WHY is this?*

A. Because little *motes* and *particles of dust* (thrown into agitation by the *convective currents* of the air) are made *visible* by the strong beam of light, thrown into the room through the crevice of the shutter.

Q. *Why can we not SEE the air?*

A. Because it is perfectly transparent, i.e. permits all the rays of light to pass through it without reflecting any.

Q. *Why does water RISE in a common pump?*

A. Because the *pressure* of the *air* is removed from the water in the *pipe of the pump* by the action of the *sucker*; but not from the water in the well.

Take a tube (shaped like a U) partially filled with water, and let an equal weight be fitted to each orifice: so long as the weights are undisturbed, the water will remain at the same level on both sides of the tube; but if one weight be removed, its place will be instantly occupied with an equal weight of water. So in a pump, the air may be compared to these two weights; as the action of the sucker removes *one*, water rushes into the pipe to counterbalance the weight of air pressing on the water in the well.

Q. *How high can atmospheric PRESSURE make water rise in the pipe of a pump?*

A. About 30 feet above the level of the water in the well.

It would be nearly 34 feet if the pump were of perfect construction. Because a column of water 34 feet high, weighs the same as an equal-size column of air, reaching to the top of the atmosphere. N. B. The atmospheric pressure is 15 pounds on each square inch.

Q. *How is water PUMPED from a well more than 30 feet deep?*

A. The piston-rod is made to extend within 30 feet of the water in the well; and when the water has risen thus high, it passes through a valve in the sucker, and is *lifted* out of the pump by the piston box.

The water is *lifted* from deep wells, and never *sucked* up beyond 30 feet.

Q. *Why does a syphon \*EMPTY a vessel of its liquid?*

A. Because one side of the bent tube being *longer* than the other, contains a *greater weight* of water, and the *balance* is destroyed.

The unequal weight of water in the two tubes, causes the water of the longer tube to fall out and produce a vacuum. In a common PUMP the vacuum is produced by the mechanical action of the sucker.

Q. *Why is it often difficult and painful to breathe on a mountain top?*

A. Because the *pressure* of the air on a mountain top is not so great as on a plain. Consequently the fluids in the body *expand*, and painfully *stretch* the membranes which contain them.

Q. *Why do we often feel OPPRESSED just previous to a storm?*

A. Because the air is greatly rarefied; and the *removal* of *pressure* from the surface of the body, causes a painful distension.

Q. *How do you know that the density of the air is lowered, previous to a storm?*

A. Because the *mercury* of a barometer rapidly *falls*.

The mercury in the tube of the barometer is held up, like the water in the tube of the pump, by the pressure of the atmosphere.

Q. *Why do CORNS ache previously to RAIN?*

A. Because the rarefied state of the air causes *distension* in the tissues of the feet; and as the *hard corn* cannot swell equally with the *softer parts*, irritation is produced in the fibrils of the nerves.

Q. *Why do CELLARS feel WARM in WINTER?*

A. Because the external air has not

free access into them; in consequence of which, they remain almost at an *even temperature*,—which (in winter time) is about 10 degrees *warmer*, than the external air.

Q. *Why do CELLARS feel COLD in SUMMER?*

A. Because the external air has not 'free access into them; in consequence of which, they remain almost at an *even temperature*,—which (in summer time) is about 10 degrees *colder*, than the external air.

Q. *Why does AIR rust IRON?*

A. Because the *oxygen of the air* combines with the *surface* of the metal, and produces *oxide of iron*: which is generally called "rust."

An oxide of iron, copper, &c., is oxygen in *combination* with iron, copper, &c.,

Q. *Why does hot iron SCALE and PEEL off, when struck with a HAMMER?*

A. Because the *oxygen of the air* very readily unites with the surface of *hot iron*, and forms a metallic oxide (or rust), which scales off, when struck with a hammer.

Q. *Does iron RUST in DRY air ?*

A. No ; iron undergoes no change in dry air.

Q. *Why do STOVES and FIRE-IRONS become RUSTY in rooms, which are not OCCUPIED ?*

A. Because the air is damp ; and moist air *oxidizes* iron and steel.

Oxidizes, i. e. rusts.

Q. *In what part of the year is it most difficult to keep STOVES and FIRE-IRONS BRIGHT ?*

A. In autumn and winter.

Q. *Why is it more difficult to keep STOVES and FIRE-IRONS bright in autumn and winter, than in spring and summer ?*

A. Because the capacity of the air for holding water is constantly on the decrease, after the summer is over : in consequence of which, vapour is deposited on everything with which the air comes in contact.

Q. *Why does GREASING iron prevent its becoming RUSTY ?*

A. Because grease prevents the humidity of air from coming in contact with the surface of the iron.

Q. *Why do not stoves rust, so frequently as POKERS and TONGS ?*

A. Because stoves are generally covered with *plumbago*, or black lead.

Q. *What is plumbago or black lead?*

A. A mixture of charcoal and iron.

Plumbago (strictly speaking) is a chemical union of *carbon* and *iron*, in the following proportions:—91 parts carbon and 9 iron. But the **BLACK LEAD** sold in shops is a mixture of charcoal and iron filings.

N. B. A most excellent varnish to prevent rust is made of 1 pint of fat-oil varnish, mixed with 5 pints of highly rectified spirits of turpentine, rubbed on the iron or steel with a piece of sponge. This varnish may be applied to bright stoves, and even mathematical instruments, without injuring their delicate polish.

Q. *Why does ornamental STEEL (of a purple or LILAC colour) rust more readily, than polished WHITE steel?*

A. Because the lilac tinge is produced by *partial oxidation*; and the process which forms rust has already commenced.

Q. *How can lilac STEEL be kept FREE from RUST?*

A. By keeping it in a *dry place*.

Q. *If DRY AIR contains OXYGEN, why does it NOT RUST IRON, as well as MOIST air?*

A. Because moisture is necessary to bring into action the affinity of oxygen for steel.

Water is decomposed by contact with iron; but it is chiefly the *oxygen* of water which *rusts* iron. Even **DRY AIR** oxidizes iron at a high temperature, thus a red-hot poker is rusty, when it cools.

Q. *Do any OTHER metals (besides iron) combine rapidly with oxygen?*

A. Yes ; copper, zinc, lead, mercury ; and even silver oxidizes to some extent.

Q. *Why do COPPER and ZINC tarnish ?*

A. The tarnish of copper and zinc is caused by their *oxidation* : that is, oxygen from the moist air combines with the surface of the metals, and (instead of *rusting them*) covers them with a *dark tarnish*.

Q. *Why does LEAD become of a DARKER hue, by being exposed to the air ?*

A. Because the oxygen of the moist air combines with the lead, and *oxidizes its surface* ; which instead of becoming *rusty*, assumes a *darker hue*.

Q. *Why does lead lose its brightness, and become DULL, by being exposed to the air ?*

A. The *dullness* of the lead is caused by the presence of a *carbonate* of the oxide : When the oxide is formed, it attracts *carbonic acid* from the air, and by combining with it produces a *carbonate*, which gives the *dull* tint to old lead.

Q. *Why is it difficult to keep silver BRIGHT ?*

A. Because the vapour of the air oxidizes its surface, and *tarnishes it*.



The tarnish of silver forks and spoons, is often due to the sulphur and sulphuretted hydrogen of certain foods united to the silver by saliva, according to a regular galvanic process. N. B. Without saliva egg spoons, &c. will not tarnish from food, because the galvanic influence is not brought into action.

Q. *Why do silver TEA-POTS and SPOONS tarnish more quickly, than silver ore or bullion?*

A. Because alloy of some *baser* metal is used, to make them more *hard and "lasting"*; and this *alloy* oxidizes more quickly, than silver itself.

Q. *Why does GERMAN silver turn a dingy yellow in a few hours?*

A. Because German silver has a great affinity for oxygen; and shows its oxidation by a *yellow tarnish*, instead of rust.

Q. *If quicksilver (or mercury) will tarnish like copper and lead—why does it preserve its brilliancy in BAROMETERS and THERMOMETERS?*

A. Because the *air* is excluded; and no moisture can come in contact with it, to *oxidize* (or *tarnish*) it.

Q. *Is GOLD affected by the atmosphere?*

A. Not readily; gold will never combine with oxygen of itself, (i. e. without aid).

Q. *WHICH of the metals is capable of resisting oxidation altogether?*

A. Platinum; in consequence of

which, the graduated arcs of delicate "instruments for observation" are made of plat'inum, in preference to *other* metals.

Before plat'inum was known, gold was used for this purpose.

Q. *Why is PLAT'INUM used for the graduated arcs of delicate mathematical instruments, instead of any other metal?*

A. Because it will never oxidize; but, retains its *bright surface* in all weathers, free from both *rust* and *tarnish*.

"Platinum," (a white metal), so called from "*plata*," the Spanish word for *silver*. It was introduced from South America into England by Mr. Wood, (A.D. 1749).

Q. *For what other SCIENTIFIC purpose is PLAT'INUM now used?*

A. For the construction of crucibles in which *acids* are to be employed; and for the formation of some of the plates for galvanic batteries.

Q. *Why are CRUCIBLES (in which acids are employed) made of PLAT'INUM?*

A. Because the acid would act upon *other metals*, or upon *glass*; and prevent the experimenter's success.

Q. *Which of the METALS have the greatest affinity for OXYGEN?*

A. Those called *potas'sium* and *so'dium*.

## OXIDES.

Potas'sium and so'dium derive their names from potash and soda. Potas'sa is the oxide of potas'sium; and soda is the oxide of so'dium.

Q. *How is the affinity of potas'sium and so'dium for oxygen shewn?*

A. They *decompose water* immediately they are brought into contact with it.

Q. *What effect has POTAS'SIUM on water?*

A. It *decomposes* it. The hydrogen being set free, combines with the oxygen of the air, and is ignited by the latent heat liberated from the potassium.

N. B. Water is composed of oxygen and hydrogen; Potassium *separates* these two gases.

Q. *What effect has SO'DIUM on water?*

A. It does not produce *flame*, as potassium does; but it decomposes water, and undergoes very rapid *oxidation*.

Q. *Is the FURR of KETTLES an oxide?*

A. No; the furr (or deposit of boiling water) is a precipitate of *lime and mineral salt*, separated from water by the process of boiling.

Q. *Is not the FURR of boiling water often DANGEROUS?*

A. Yes; especially in *tubular boilers*, such as those employed in railways.

Q. *Why is FURR especially troublesome in RAILWAY engines?*

A. Because it is a *bad conductor* of heat: in consequence of which, it hinders the process of *evaporation*; and as more fuel is required to produce the needful amount of steam, a great waste of fuel is incurred.

Q. *Why is FURR especially DANGEROUS in RAILWAY engines?*

A. Because the boilers are likely to become *over-heated*, when furr is deposited in them, as the water is no longer in immediate contact with the metal itself: When this is the case, *explosion* may occur from the sudden generation of highly elastic steam.

Q. *Why are RAILWAY engines never fed with BRACKISH water?*

A. Because *brackish* water contains much *mineral matter*; which causes a large deposit of furr.

Furr may be removed from kettles by boiling in them a little sal-ammoniac (*hydrochlorate of ammonia*). The hydrochloric acid unites with the lime of the furr, and the carbonic acid goes to the ammonia. Both of these new compounds dissolve, and wash away most easily.

## CHAPTER XIX.

## CARBONIC ACID GAS.

Q. *What is CARBONIC ACID gas?*

A. A gas formed by the union of carbon and oxygen: It used to be called "FIXED AIR."

3 lbs. of carbon and 8 lbs. of oxygen will form 11 lbs. of carbonic acid. It may be obtained and collected in the usual way, by pouring a mixture of one part of muriatic acid, and 10 of water, on pounded marble contained in a retort.

Q. *Under what circumstances does CARBON most readily unite with OXYGEN?*

A. 1st—When its temperature is raised: Thus if carbon be red hot, oxygen will most readily unite with it: and

2ndly—When it forms part of the fluid blood.

Q. *Why do oxygen and carbon so readily unite in the BLOOD?*

A. Because the atoms of carbon are so loosely attracted by the other materials of the blood, that they unite very readily with the oxygen of the air inhaled.

Q. *Is carbonic acid WHOLESOME?*

A. No; it is *fatal to animal life*; and (whenever inhaled) acts like a narcotic poison, producing drowsiness, which sometimes ends in death.

Q. *How can any one KNOW, if a place be infested with CARBONIC ACID gas?*

A. If a pit or well contain carbonic acid, a *candle* (let down into it) will be *instantly extinguished*. The rule, therefore, is this—Where a *candle will burn, a man can live*; but what will *extinguish* a candle, will also *destroy* life.

Q. *Why does a MINER lower a CANDLE to the bottom of a mine, before he descends?*

A. Because a candle will be *extinguished*, if the mine contain carbonic acid gas: but if the candle be *not* extinguished, a man may fearlessly descend.

Q. *Why do well-sinkers often let down buckets of fresh-slacked LIME in wells, before they descend?*

A. Because if carbonic acid be present, the lime will absorb it to form carbonate of lime.

Q. *Why does a CROWDED ROOM produce HEAD-ACHE?*

A. Because its air is *vitiated* by the action of many human lungs. . A a 2

Q. *Why is the air of a room vitiated by a crowd?*

A. Because it is deprived of its due proportion of *oxygen*, and laden with *carbonic acid*.

Q. *How is the air of a room vitiated by a crowd?*

A. The *elements* of the air inhaled are *separated* in the *lungs*:—A part of the *oxygen* is converted in the blood into *carbonic acid*; and then thrown back again with the breath into the room.

Q. *Why are sailors occasionally killed when sent to examine the well of a ship?*

A. Because it contains *carbonic acid*, probably given off from some part of the cargo, in consequence of its fermentation. This gas remains in the lowest hollows of the hull, in consequence of its great weight.

'rice and coffee sometimes get damp from leakage, and then ferment and throw off vast quantities of carbonic acid. March 1, 1817, four men were killed in the trading ship, *Grab Hawoody*, in its voyage from Calcutta, in consequence of being sent to examine the well containing carbonic acid, given off from some damp rice.

Q. *Mention the historical circumstances, so well known in connexion with the "BLACK HOLE" of Calcutta.*

A. In the reign of George II., the

Raja (or Prince) of Bengal marched suddenly to Calcutta, to drive the English from the country; as the attack was unexpected, the English were obliged to submit, and 146 persons were taken prisoners.

The Sur Raja, at Dowlat; a young man of violent passions, who had but just succeeded to the throne. A. D. 1756.

Q. *What became of these prisoners?*

A. They were driven into a place about 18 feet square, and 15 or 16 feet in height, with only two small grated windows. 123 died in one night; and (of the 23 who survived) the larger portion died of putrid fevers, after they were liberated.

Q. *Why were 123 persons SUFFOCATED in a few hours, from confinement in this close hot*

A. Because the *oxygen* of the air was soon *consumed* by so many lungs, and its place supplied by *carbonic acid*, exhaled with the hot breath.

Q. *Why did the captives in the BLACK HOLE die SLEEPING?*

A. 1st—Because the *absence of oxy-*



*gen* quickly affects the vital functions, depresses the nervous energies, and produces great lassitude: and

2ndly—*Carbonic acid* (being a narcotic poison) produces *drowsiness* in those who inhale it, before it kills them.

The floor of the Grotto del Canè, in Italy (i.e. Cavern of Dogs) is always laden with carbonic acid. It is a common practice with the guides who show it, to drive dogs in, and cause them to suffer a temporary death. A man may safely enter the cavern, because his mouth reaches far above the noxious gas, which, being nearly twice as heavy as air, settles on the bottom of the cave.

The Lake Averno, which Virgil supposed to be the entrance to the infernal regions, gives out so much of this gas, that birds, flying over it, are suffocated. Lake Averno means, *the lake destructive to birds*.

Q. *Why are the JUNGLES of Java and Hindostan so FATAL to life?*

A. Because vast quantities of *carbonic acid* are thrown off by decaying *vegetables* in these jungles; and (as the wind cannot penetrate the thick brushwood, to blow the pernicious gas away) it *settles* there, and destroys animal life.

The Valley of Death, in Java, is covered with the skeletons of birds, beasts, and human beings, which have been suffocated by the carbonic acid gas which abounds in the fatal valley.

Q. *Why do persons in a crowded CHURCH feel DROWSY?*

A. 1st—Because a *large portion* of the *oxygen* of the air, which alone can

sustain healthy action, has been consumed by the lungs of the congregation: and

2ndly—The air of the church is impregnated with carbonic acid gas, which (being a strong narcotic) produces drowsiness in those who inhale it.

Q. *Why do persons, who are much in the OPEN AIR, enjoy the best health?*

A. Because the air they inhale is *much more pure.*

Q. *Why is COUNTRY AIR more pure, than the air in CITIES?*

A. 1st—Because there are fewer inhabitants to vitiate the air:

2ndly—There are more trees to restore the pure character of the vitiated air: and

3rdly—The free circulation of air prevents the accumulation of vitiated products.

For the same reason, running streams are pure and wholesome, while stagnant waters are the contrary.

Q. *Why does the SCANTINESS of a country population render the COUNTRY AIR more pure?*

A. Because the fewer the inhabitants, the *less carbonic acid* will be thrown into

the atmosphere; and thus country people inhale *pure air*, instead of air impregnated with carbonic acid gas.

Q. *Why do trees and flowers help to make country air WHOLESOME?*

A. 1st—Because they *absorb* the *carbonic acid* generated by the lungs of animals, putrid substances, and other noxious exhalations: and

2ndly—Trees and flowers restore to the air the *oxygen*, contained in the carbonic acid which they absorb.

Q. *Why is the air of CITIES less wholesome, than COUNTRY air?*

A. 1st—Because there are more *inhabitants* to vitiate the air:

2ndly—The *sewers, drains, bins, and filth* of a *city*, very greatly vitiate the air:

3rdly—The streets and alleys prevent a free circulation: and

4thly—There are fewer trees to absorb the excess of carbonic acid gas, and restore *oxygen*.

Q. *Why are persons, <sup>a</sup>who live in close rooms and crowded cities, generally SICKLY?*

A. Because the air they breathe is

not pure ; but is both *defective in oxygen*, and also impregnated with *carbonic acid*.

Q. *Where does the carbonic acid of close rooms and cities* COME from ?

A. From the lungs of the inhabitants, the sewers, drains, and other like places, in which organic substances are undergoing *decomposition*.

Q. *What* BECOMES of the *carbonic acid* of crowded cities ?

A. Some of it is *absorbed* by *vegetables* ; and the rest is *blown away* by the *wind*, and diffused through the whole volume of the air.

Q. *Does not this constant diffusion of carbonic acid affect the PURITY of the WHOLE air ?*

A. No ; because it is wafted by the wind from place to place, and *absorbed* in its passage by the *vegetable world*.

Q. *What* is CHOKE DAMP ?

A. *Carbonic acid gas* accumulated at the bottom of wells and pits ; which renders them noxious, and often fatal to life.

Q. *Why is not this carbonic acid* TAKEN UP by the air and DIFFUSED, as it is in cities ?

A. Because it *cannot rise* from the *well* or *pit*, in consequence of being heavier than air; and no wind can get to it, to help its diffusion.

47½ lbs. of carbonic acid weigh as much as 100 lbs. of atmospheric air.

Q. *Why are persons sometimes KILLED, by leaning over BEER VATS?*

A. Because vats (where beer has been made) contain large quantities of *carbonic acid gas*, produced by the “vinous fermentation” of the beer; and when a man incautiously *leans over a beer vat*, and inhales the carbonic acid, he is immediately *killed* thereby.

Q. *Why are persons often KILLED, who enter BEER VATS to clean them?*

A. Because carbonic acid (being heavier than *atmospheric air*) often rests upon the *bottom of a vat*: when, therefore, a person enters it, and *stoops to clean the bottom*, he inhales the pernicious gas, which *kills* him.

Q. *Why are persons sometimes killed by having a CHARCOAL FIRE in their bedrooms?*

A. Because the *carbon* of burning charcoal unites with the *oxygen* of air,

and forms *carbonic acid gas*; which is a narcotic poison.

Q. *If carbonic acid settles at the BOTTOM of a room, how can it injure a person LYING upon a BED, raised considerably above the floor?*

A. All gases *diffuse* themselves *through each other*, as a drop of *ink* would diffuse itself through a cup of water. If, therefore, a person slept for 6 or 8 hours in a room containing carbonic acid, quite enough of the gas will be diffused throughout the room to produce death.

The *heat* of the fire assists the process of diffusion.

Q. *What are the chief sources of CARBONIC ACID?*

A. 1st—The breath of animals:

2ndly—The decomposition of vegetable and animal matter: and

3rdly—Lime-stone, chalk, and all calcareous stones,—in which it exists in a *solid* form.

Q. *From which of these sources is carbonic acid most likely to ACCUMULATE to a noxious extent?*

A. From the fermentation and putrefaction of decaying vegetable and animal matters.

Q. *How can this accumulation of carbonic acid be PREVENTED?*

A. By throwing *fresh-slaked lime* into places, where such fermentation and putrefaction are going on.

Q. *How will FRESH-SLAKED LIME prevent the accumulation of carbonic acid?*

A. By *absorbing* it; and producing a combination called "carbonate of lime."

When lime is slaked, all its carbonic acid is driven off by the heat; therefore, it is free to combine with more.

Q. *Does not heavy RAIN prevent the accumulation of carbonic acid, as well as quick-lime?*

A. Yes; an abundant supply of *water* will prevent the accumulation of carbonic acid, by *dissolving* it.

N. B. Red heat (as a pan of red-hot coals, or a piece of red-hot iron) will also soon disperse the carbonic acid gas, accumulated in a pit or well.

Q. *What effect has carbonic acid on the WATER, in which it is dissolved?*

A. It renders it slightly *acid* to the taste.

Q. *Can the CAPACITY of water for dissolving carbonic acid be increased?*

A. Yes. Carbonic acid may be *forced* into water by *pressure* to a considerable extent.

Q. *To what practical USES has this capacity of water (for dissolving carbonic acid) been applied ?*

A. *Effervescing draughts* are made upon this principle.

Q. *Explain the cause of EFFERVESCENCE in these beverages.*

A. The carbonic acid of the beverage (imprisoned by the cork) is *forced* into the liquor by pressure, and *absorbed* by it: but when the cork is removed, the carbonic acid flies off in *bubbles or effervescence*.

Q. *Why does AERATED water effervesce when the CORK is removed ?*

A. While the bottle remains *corked*, the carbonic acid is *forced* into the water by pressure, and absorbed by it: but when the cork is *removed*, it flies off in *effervescence*.

Q. *Why does SODA WATER effervesce ?*

A. Because it contains 8 times its own bulk of carbonic acid gas, which has been forced into it by pressure; which makes its escape in *effervescence*, as soon as the *cork is removed*.

Q. *Why does GINGER POP fly about in froth, when the string of the cork is cut ?*



A. Because it contains carbonic acid gas. While the *cork is fast*, the carbonic acid is *forced* into the liquor; but when the *pressure is removed*, the gas is given off in *effervescence*.

N. B. All vinous fermentation produces carbonic acid.

Q. *Why does BOTTLED ale froth more, than DRAUGHT ale?*

A. Because the *pressure* is greater in a *bottle*, than in a *tub* which is continually *tapped*: and the amount of effervescence is always in proportion to the *pressure* to which the liquid has been subjected.

Q. *What produces the FROTH of BOTTLED porter?*

A. *Carbonic acid*, generated by the *vinous fermentation* of the *porter*: This gas is *absorbed* by the *liquor*, so long as the bottle is well *corked*; but is given off in froth, when the *pressure* of the *cork* is removed.

Q. *What gives the pleasant ACID taste to soda water, ginger beer, champagne, and cider?*

A. The presence of *carbonic acid*, generated by fermentation; and liberated

by effervescence, when the pressure of the cork is removed.

Q. *Why does fresh SPRING WATER SPARKLE, when poured from one vessel to another ?*

A. Because fresh spring and pump water contain *carbonic acid*; and the presence of this gas makes the water *sparkle*.

Much of the froth and bubbling of ale, beer, WATER, &c. when they are "poured high," is due to common air imprisoned by the action of dropping water.

Q. *What is the FERMENTATION of BEER and WINE ?*

A. The escape of carbonic acid, produced by the change of *sugar* into *al'cohol*.

Q. *What is AL'COHOL ?*

A. The *spirit* of beer and wine, obtained by fermentation.

Q. *Of what ELEMENTS is AL'COHOL composed ?*

A. Of carbon, oxygen, and hydrogen.

Of AL'COHOL, 4 parts are carbon ; 2 oxygen ; and 6 hydrogen.

Q. *What are the ELEMENTS of grape SUGAR ?*

A. Carbon, oxygen, and hydrogen, all in equal proportions.

Q. *What CHANGES does SUGAR undergo by FERMENTATION ?*

A. It is first decomposed ; and then

its elements re-unite in different proportions ; producing *alcohol*, *carbonic acid*, and *water*.

Of SUGAR, one portion is alcohol ; and another carbonic acid : as may be seen by the following table :

| Every atom of anhydrous sugar contains | Carbon.<br>12 | Oxygen.<br>12 | Hydro.<br>12 |
|----------------------------------------|---------------|---------------|--------------|
| Two atoms of Alcohol contain           | 8             | 4             | 12           |
| Four atoms of carbonic acid contain    | 4             | 8             | 0            |
|                                        | 12            | 12            | 12           |

N.B. "Anhydrous sugar" is sugar *dried* at 300°.

Q. *How does SUGAR form ALCOHOL by fermentation ?*

A. *Two-thirds* of its carbon and *one-third* of its oxygen re-unite with the hydrogen, and generate *alcohol*.

Q. *How does SUGAR form carbonic acid by fermentation ?*

A. The remaining *one-third* of its carbon and *two-thirds* of its oxygen re-unite, and generate *carbonic acid*.

Q. *What BECOMES of the alcohol, which is thus generated by fermentation ?*

A. It mixes with the *water*, and forms the *intoxicating* part of beer and wine.

Q. *What is the most common reason for beer, wine, and other fermented liquors turning sour ?*

A. Air gets to them, and its oxygen acidifies the alcohol, turning it into vinegar.

Sugar passes at once into vinegar, when it is fermented in the open air.

Q. *Why is BARLEY MALTED?*

A. Because *germination* is produced by the artificial heat; and in germination, the *starch* of the *grain* is converted into *sugar*.

Q. *How is barley malted?*

A. It is *moistened with water*, and *heaped up*; by which means, great heat is produced, which makes the *barley sprout*.

See "spontaneous combustion," p. 57.

Q. *Why is not the barley suffered to GROW as well as SPROUT?*

A. Because plants in the *germ* contain more sugar, that in any *other* state; as soon as the germ *puts forth shoots*, the *sugar* of the plant is *consumed*, to support the shoot.

Q. *How is barley PREVENTED from SHOOTING, in the process of MALTING?*

A. It is put into a *kiln*, as soon as it sprouts; and the heat of the kiln checks or destroys the young shoot. B a 3

Q. *What is YEAST?*

A. The foam of beer (or of some similar liquor) produced by *fermentation*.

Q. *Why is YEAST used in BREWING?*

A. Because it consists of a substance called *glu'ten*, undergoing putrefaction; in which state it possesses the peculiar property of exciting *fermentation*.

If the gluten were not in a putrefying state, it could not produce fermentation.

Q. *What is glu'ten?*

A. A tough elastic substance, composed of carbon, oxygen, hydrogen, and nitrogen.

It is the presence of nitrogen which gives yeast the power to excite fermentation.

Q. *Does MALT contain glu'ten?*

A. Yes. The infusion of malt, called "sweet-wort," contains an *abundance* of *glu'ten*; and the yeast (which converts its *sugar* into *al'cohol*) converts this *glu'ten* into *yeast*.

Q. *Why is YEAST needful, in order to make the infusion of malt into BEER?*

A. Because the presence of a putrefying body containing nitrogen is essential, in order to convert sugar into *al'cohol*.

Q. *What EFFECT has yeast upon the sweet-wort?*

A. It causes the SUGAR of the wort to be converted into *al'cohol* and *carbonic acid*; and its GLUTEN into yeast.

Q. *What change is produced in glu'ten by PUTREFACTION?*

A. Its elements are loosened from their former *conditions of combination*, and re-arranged (with the addition of oxygen from the air) into a *new series*.

Q. *What is the difference between FERMENTATION and PUTREFACTION?*

A. FERMENTATION is a change effected in the elements of a body composed of carbon, oxygen, and hydrogen, *without nitrogen*. PUTREFACTION is a change effected in the elements of a body composed of carbon, oxygen, hydrogen, and *nitrogen*.

Q. *What NEW COMPOUNDS are produced by the change called fermentation?*

A. *Al'cohol* and *carbonic acid*.—The alcohol is still further changed (unless the process be checked) into *ac'e'tic acid* or *vinegar*. ✓

Q. *What new compounds are produced by the change called PUTREFACTION ?*

A. The carbon, oxygen, hydrogen, and nitrogen, of the original substance (being separated by decomposition) reunite in the following manner. 1. Carbon and oxygen unite to form *carbonic acid*. 2. Oxygen and hydrogen unite to form *water*. 3. Hydrogen and nitrogen unite to form *ammonia*.

*Hartshorn* is a solution of ammonia in water.

N. B. When bodies containing sulphur and phosphorus putrefy, the *sulphur* and *phosphorus* unite with *hydrogen*, and form *sulphuretted* and *phosphuretted hydrogen* gases.

Q. *What BECOME of these several products of putrefaction ?*

A. They are all elastic bodies, and *escape into the air*.

N. B. *Water* in the condition of *vapour*, is both elastic and gaseous.

Q. *What is the cause of the OFFENSIVE SMELL which issues from putrefying bodies ?*

A. The evolution of *ammonia*, or of *sulphuretted* and *phosphuretted hydrogen* gases; all of which have pungent and offensive odours.

Q. *Why do boiled EGGS DISCOLOUR a SILVER SPOON ?*

A. Because they contain a small portion of *sulphur*, which *unites with the silver*, and *tarnishes it* as soon as it moistened with saliva.

Both the white and yolk contain sulphur—the latter more abundantly. The tarnish is a sulphuret of silver, and may be easily removed by rubbing with hartshorn or table salt.

Q. *What causes the offensive smell of STALE hard boiled EGGS?*

A. The *hydrogen* of the egg combining with its *sulphur* and *phosphorus*, form *sulphuretted* and *phosphuretted hydrogen*; both of which gases have an offensive odour.

Of an egg 55 parts are carbon, 16 nitrogen, 7 hydrogen, and the remaining 22 are oxygen, phosphorus, and sulphur.

Q. *Why is it NOT needful to put YEAST into GRAPE juice, in order to produce fermentation?*

A. Because grape juice contains a sufficient quantity of a nitrogenized substance like *yeast*, to produce fermentation without it.

Nitrogenized, i. e. containing nitrogen.

Q. *Why do not GRAPES ferment, while they hang on the VINE?*

A. Because the *water of the juice* evaporates through the skin, and allows the grapes to shrivel and dry up, after they are ripe.



Fermentation cannot occur unless the sugar be dissolved in a sufficient quantity of *water*.

Q. *What is the FROTH or SCUM of fermented liquors?*

A. Putrefying glutinous substances (resembling yeast), which rise to the surface from their *lightness*.

Q. *Why is beer FLAT, if the cask be left open too long?*

A. Because too much of the *carbonic acid gas*, (produced by fermentation) is suffered to escape.

Q. *Why are beer and porter made stale by being exposed to the AIR?*

A. Because too much of the *carbonic acid gas* (produced by fermentation) is suffered to escape.

Q. *Why does beer turn FLAT, if the VENT PEG be left out of the tub?*

A. Because the *carbonic acid gas* escapes through the vent hole.

Q. *Why will NOT beer run out of a tub, till the VENT PEG is taken out?*

A. Because the upward pressure of the external air (admitted through the *tap*) holds the liquor back,—not being counterbalanced by any pressure of air on the *surface* of the liquid.

The *upward* pressure of air may be illustrated by the following simple experiment:—Fill a wine glass with water; cover the top of the glass with a piece of writing paper; turn the glass upside down, and the water will not run out. The paper is used merely to give the air a medium sufficiently dense to act against.

Q. *Why does the beer run FREELY, immediately the VENT PEG is taken out ?*

A. Because air rushes immediately *through the vent hole at the top of the tub*, to counterbalance the air admitted by the tap; in consequence of which the liquid escapes by its own weight.

Q. *Why does liquor flow reluctantly out of a BOTTLE held upside down ?*

A. Because the *upward pressure of the air*, interferes with its free escape from the narrow mouth of the bottle.

Q. *Why should a bottle be held OBLIQUELY, in order to be emptied of its liquor ?*

A. Because the liquor will then run out by the *under portion* of the neck, and allow the air to flow in by the *upper part* to counterbalance the upward pressure.

Q. *Why does wine (poured from a bottle QUICKLY) spirt about, without going into the decanter ?*

A. Because it fills the *top of the decanter* (like a cork), and leaves *no room*

for the air inside *to escape* ; the decanter, therefore, (being *full of air*) refuses to admit the wine.

Q. *Why does the EFFERVESCENCE of soda water and ginger beer very soon go off?*

A. Because the *carbonic acid*, (which produced the effervescence) very rapidly *escapes* into the air.

Q. *Why is boiled water FLAT and insipid?*

A. Because the whole of the *carbonic acid* is expelled by boiling, and escapes *into the air*.

Q. *Why does YEAST make bread LIGHT?*

A. Because it produces a species of fermentation on the starch and gluten of flour, as it does in the sugar of malt.

Q. *How does FERMENTATION make the dough RISE?*

A. During fermentation, *carbonic acid gas* is evolved ; but the sticky texture of the dough will not allow it to *escape* ; so it *forces up little bladders* all through the dough.

Q. *Why is DOUGH placed before a fire?*

A. 1st—Because the heat of the fire *increases fermentation* : and

2ndly—It *expands the gas* confined in the little bladders; in consequence of which, the bubbles are *enlarged*, and the dough becomes lighter and more porous.

Q. *Why is bread HEAVY, if the dough be removed from the fire?*

A. Because the dough *gets cold*, and the air in the bladders *condenses*: In consequence of which, the paste falls,—and the bread becomes close and heavy.

Q. *Why is wheaten bread more NUTRITIOUS than that made from any other grain?*

A. Because wheat contains more gluten than other grains, on which its nutritive quality depends.

Good wheat flour contains about 25 per cent of gluten.

Q. *What causes the HEAT of fire?*

A. The heated carbon of fuel *combines* with *oxygen* from the *air*, and produces *carbonic acid gas*, by which chemical action *heat* is evolved.

Q. *What causes the heat of animal bodies?*

A. The *carbon* of the *blood* combines with *oxygen* from the *air inhaled*, and produces *carbonic acid gas*; which evolves heat in a way similar to burning fuel.

Q. *Whence does the HEAT of a DUNGHILL arise?*

A. The straw, &c. of the *dunghill*, undergoes *fermentation* from decay, and produces *carbonic acid gas*; from which heat is evolved by a species of combustion, as in the two former cases.

Q. *How does the formation of CARBONIC ACID (in all these cases) produce HEAT?*

A. Carbonic acid has less power of holding *latent heat*, than *carbon* and *oxygen* have: when, therefore, these elements are changed into carbonic acid, latent heat is given off, and made *sensible*.

Q. *Why do persons throw LIME into bins and sewers, to PREVENT their offensive smell in summer-time?*

A. Because they contain various gases, which readily *combine with lime*; and neutralize their offensive odours.

Q. *Why should WATER (used for washing) be exposed to the air?*

A. Because it is made *softer* by exposure to the air.

Most spring water holds lime in solution as a *bicarbonate*, in consequence of the presence of abundant carbonic acid. Carbonic acid escapes by exposure to air—and the lime is consequently, deposited as a carbonate. The bicarbonate of lime contains twice as much carbonic acid as the carbonate.

Q. *Why is hard WATER made SOFTER by exposure to air?*

A. 1st—Because the mineral *salts* (which cause its hardness) *subside*: and

2ndly—Because the carbonic acid of the water makes its escape into the air.

Q. *How is the carbonic acid of water produced?*

A. By the presence of what is called the bicarbonate of *lime*, which is frequently held in solution by hard water.

Bicarbonate of lime is a salt, composed of lime and carbonic acid.

Q. *Why is HARD WATER more agreeable to DRINK, than soft water?*

A. Chiefly because it contains carbonic acid.

Q. *Why is water, FRESH from the pump, more SPARKLING, than after it has been drawn some time?*

A. Because water fresh from the pump contains carbonic acid, which soon escapes into the air, and leaves the water flat and stale.

Q. *Why is QUICK-LIME formed by subjecting chalk and limestone to intense heat in a kiln?*

A. Because the *carbonic acid* (which rendered it *mild*) is driven off by the

heat of the kiln : and the lime becomes *quick* or *caustic*.

Chalk and lime-stone are not *burnt*, but *calcined* by the heat of the kiln.

Q. *What is MORTAR ?*

A. Lime mixed with sand and water.

Q. *What is the difference between QUICK-LIME and SLACKED-LIME ?*

A. Slacked-lime is quick-lime to which water has been added.

When quick-lime is slacked, by the addition of water, great heat is given out ; the *latent heat* of the fluid water being made sensible when it becomes solid by uniting with the lime.

Q. *Why does MORTAR become HARD, after a few days ?*

A. Because the lime *re-imbibes* from the air the carbonic acid which had been *expelled by fire* ; and the loose powder again becomes as hard as the original *lime-stone*.

Q. *Explain in what way MORTAR is adhesive.*

A. When the carbonic acid is expelled, the hard lime-stone is converted into a loose *powder*, which (being mixed with sand and water) becomes a soft and sticky *plaster* ; but, as soon as it is placed between bricks, it *re-imbibes* carbonic acid and hardens into *lime-stone* again.

## CHAPTER XX.

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CARBURETTED  
HYDROGEN GAS.

Q. *What is* CHOKE-DAMP?

A. *Carbonic acid gas* accumulated at the bottom of wells and pits. It is called CHOKE damp, because it *chokes* (or suffocates) *every animal* that attempts to *inhale it* (see p. 266).

It suffocates without getting into the *lungs*, by closing the outer orifice *spasmodically*.

Q. *What is* marsh-gas or FIRE-DAMP?

A. *Carburetted hydrogen gas* accumulated on marshes, in stagnant waters, and coal pits; it is frequently called “*inflammable air*.”

Q. *What is* CARBURETTED HYDROGEN GAS?

A. *Carbon* chemically combined with *hydrogen*.

Q. *How may* CARBURETTED HYDROGEN GAS *be PROCURED on marshes*?

A. By stirring the mud at the bottom



of any stagnant pool, and collecting the gas (as it escapes upwards) in an inverted glass vessel.

Q. *What is COAL-GAS?*

A. *Carburetted hydrogen*, extracted from coals by the heat of *fire*.

Q. *Why is carburetted hydrogen gas called FIRE-DAMP, or inflammable air?*

A. Because it very readily *explodes*, when a light is introduced to it.

Provided atmospheric air be present.

Q. *Why is carburetted hydrogen gas frequently called MARSH GAS?*

A. Because it is generated in *meadows and marshes* from putrefying vegetable substances.

See ignis fatuus, 298.

Q. *What gas is evolved by the WICK of a burning CANDLE?*

A. *Carburetted hydrogen gas*: The carbon and hydrogen of the tallow combine into a gas from the heat of the flame; and this gas is called *carburetted hydrogen*.

Q. *Why does the air in coal-mines frequently EXPLODE?*

A. Because the *carburetted hydrogen*

gas (generated in these mines by the coals) having mixed with common air, explodes, when a light is incautiously introduced.

Q. *How can miners SEE in coal pits if they may never introduce a LIGHT?*

A. Sir Humphrey Davy invented a lantern for the use of miners, called "the Safety Lamp;" which may be used without danger.

Q. *Who was Sir Humphrey Davy?*

A. A very celebrated chemist, born in Cornwall, 1778; he died 1829.

Q. *What sort of thing is the SAFETY-LAMP?*

A. A kind of lantern, covered with a fine wire gauze, instead of glass or horn.

Q. *How does this fine WIRE GAUZE prevent EXPLOSION in a coal mine?*

A. By preventing the flame of the lamp from communicating with the inflammable gas of the mine.

N. B. The interstices of the wire gauze must not be fewer than 400 to a square inch.

Q. *Why will not FLAME PASS THROUGH very fine wire-GAUZE?*

A. Because metal is a very rapid conductor of heat; and when the flaming

gas (burning in the lamp) reaches the wire-gauze, so much heat is *conducted away by the wire*, that the flame cannot ignite the explosive gas of the mine.

Q. *Does the gas of a COAL-PIT get THROUGH the wire-gauze INTO the LANTERN?*

A. Yes; and the inflammable gas ignites, and burns *inside the lamp*: but no danger arises, so long as the wire-gauze does not become very much heated.

Q. *How can the miner tell when the moment of DANGER has arrived?*

A. By observing when the wire-gauze becomes *red-hot*; danger is then present: for should the heat rise *higher*, the *flame* would *pass* and produce an explosion, because the *wire* would be no longer able to cool it.

N. B. When the carburetted hydrogen gas *explodes* from a miner's candle, the miner sometimes perishes in the *blast of the flame*; and sometimes, suffers *suffocation* from the carbonic acid thus produced.

## CHAPTER XXI.

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PHOSPHURETTED  
HYDROGEN GAS.

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Q. *From what do the very OFFENSIVE EFFLUVIA of DEAD BODIES in church-yards arise?*

A. From a gas called PHOSPHURETTED HYDROGEN; which is *phosphorus* combined with *hydrogen gas*.

The escape of ammonia and sulphuretted hydrogen contributes much to this offensive odour.

Q. *What is PHOSPHORUS?*

A. A pale amber-coloured substance, resembling wax in appearance. The word is derived from two Greek words, which mean "*to produce or bring light*." ( $\phi\omega\varsigma$ - $\phi\acute{\epsilon}\rho\epsilon\iota\nu$ .)

Q. *How is PHOSPHORUS obtained?*

A. By heating bones to a white heat: by which means, the animal matter and charcoal are consumed, and a substance called "*phosphate of lime*" is left behind.

Q. *What is the PHOSPHATE OF LIME?*

A. The principal constituent of bones.

It is a compound of phosphorus, oxygen, and lime.

Phosphorus and oxygen in combination constitute phosphoric acid.

Q. *Of what is the ignitable part of LUCIFER MATCHES made?*

A. Of phosphorus; and above 250 thousand lbs. are used every year in London alone, merely for the manufacture of lucifer matches.

Q. *Why do lucifer matches so readily ignite?*

A. Because phosphorus (with which they are tipped) inflames with such a slight degree of heat, that even gentle pressure or friction will raise its temperature enough to kindle it into flame.

Q. *What is the cause of the IGNIS FATUUS, Jack o'Lantern, or Will o'the Wisp?*

A. This luminous appearance (which haunts meadows, bogs, and marshes) arises from the gas of putrefying animal and vegetable substances; especially from decaying fish.

The Welsh "Corpse Candles" are the same things.

Q. *Why are these luminous phantoms so seldom seen?*

A. Because phosphoric hydrogen is so very volatile, that it generally escapes into the air in a thinly diffused state.

If phosphorus be boiled with milk of lime, and the beak of the retort placed under water, bubbles of phosphuretted hydrogen will rise successively through the water, and (on reaching the surface) burst into flame. It is the singular property of this gas to ignite spontaneously in air when it has been produced by the action of lime or potassa on water; when the gas is procured directly from hydrated phosphorus, it does not ignite spontaneously, because it is more pure.

Q. *Why does an ignis fatuus, or Will Wisp, FLY from us when we RUN to MEET it?*

A. Because we produce a current of air in front of ourselves, (when we run towards the ignis fatuus) which drives the light gas forwards.

Q. *Why does an ignis fatuus run AFTER us, when we FLEE from it in a fright?*

A. Because we produce a current of air in the way we run, which attracts the light gas in the same course; drawing it after us, as we run away from it.

Q. *Is not a kind of Jack o'Lantern sometimes produced by insects?*

A. Yes; swarms of luminous insects passing over a meadow, sometimes produce an appearance similar to the ignis fatuus.

Q. *May not many GHOST stories have arisen from some ignis fatuus lurking about churchyards?*

A. Perhaps all the ghost stories (worthy of any credit at all) have arisen from the ignited gas of churchyards—lurking about the tombs; to which *fear* has added its own creations.

## CHAPTER XXII.

### WIND.

Q. *What is wind?*

A. Wind is *air in motion*.

Q. *What PUTS the air in motion, so as to produce WIND?*

A. The principal causes are variations of *heat and cold*; produced by the succession of day and night, and of summer and winter.

Q. *What effect has HEAT upon the air?*

A. Heat *rarefies* the air, and causes it to expand.

Q. *How do you KNOW that heat causes the air to EXPAND?*

A. If a bladder *half full of air* (tied tight round the neck) be laid before a *fire*, the air will expand by the heat, and *fill* the bladder.

Q. *What effect is produced upon air by RAREFACTION?*

A. It is made *lighter*, and *ascends through colder strata*; as a cork (put at the bottom of a basin of water) rises to the surface.

Q. *Prove that rarefied air ASCENDS.*

A. When a boy sets fire to the cotton or sponge of his balloon, the flame *heats the air*; which becomes so *light*, that it ascends, and *carries* the balloon with it.

Q. *What effect is produced upon AIR by COLD?*

A. It is *condensed*, or squeezed into a smaller compass: in consequence of which, *it becomes heavier*, and descends towards the ground.

Q. *Prove that air is condensed by COLD.*

A. Lay a bladder half full of air before a fire, till it has become fully *inflated*; if it be now removed *from* the fire, the bladder will *collapse* again, because the air condenses into its former bulk.



Q. *What is meant by the bladder "COLLAPSING?"*

A. The skin becoming *wrinkled, shrivelled, and flabby*; because there is not sufficient air inside to *fill* it.

Q. *How do you KNOW that CONDENSED air will DESCEND?*

A. Because a fire balloon *falls* to the earth, so soon as the spirit in the cotton is *burnt out*, and the air of the balloon has become *cold again*.

Q. *Does the sun heat the AIR, as it does the EARTH?*

A. No: the air is *not heated* by the *rays of the sun*; because air (like water) is a very *bad conductor*.

Q. *How is AIR HEATED?*

A. By *convection*, thus:—The *sun* heats the *earth*, and the earth *heats the air resting upon it*; this hot air *rises*, and is succeeded by *colder air*, which is heated in a similar way; till the whole volume is *warmed* by these "*convective currents*."

Q. *What is meant by "CONVECTIVE CURRENTS" of hot air?*

A. Streams of air, heated by the

earth, which *rise upwards*, and *carry heat with them*. (see p. 252.)

Q. *Is the air in a ROOM in perpetual motion, as the air ABROAD is ?*

A. Yes; there are always *two currents of air* in any room we occupy; one of *hot air* flowing *out* of the room, and another of *cold air* flowing *into* the room.

Q. *How do you KNOW, that there are these TWO currents of air in every occupied room ?*

A. If I hold a lighted candle near the *top* of the *door*, the flame will be blown *outward* (towards the *hall*); but if I hold the candle at the *bottom* of the *door*, the flame will be blown *inwards* (into the *room*).

N. B. This is not the case when a *fire* is in the room. When a fire is lighted, an inward current is drawn through *all* the crevices.

Q. *Why would the flame be blown OUTWARDS (towards the HALL), if a candle be held at the TOP of the door ?*

A. Because the air of the room, being heated, &c., *ascends*; and (floating about the upper part of the room) escapes *through the crevice* at the *top* of the *door*, producing a current of air from the room into the *hall*.

Q. *Why would the flame be blown INWARDS (into the ROOM), if a candle be held at the BOTTOM of the door ?*

A. Because the *cold air* from without is rushing *inwards*, through the crevice at the bottom of the door, to *drive* the *light warm air* out at the top.

Q. *How does warm air make its ESCAPE from a room ?*

A. The *warm air* is *pressed* out by the *cold air* coming in below ; and escapes by means of the crevices at the top of the room.

Q. *Why are not all places, which lie under the same parallel of latitude, of the same temperature ?*

A. Because various disturbing circumstances tend to vary the mean temperature.

Q. *What disturbing circumstances affect the temperature of particular situations ?*

A. 1st—The elevation and form of the land :

2ndly—The proximity of the sea :

3rdly—Mountains, swamps, and forests :

4thly—The nature of the soil : and

5thly—The prevalence of cold or warm winds.

Q. *What effect is produced on temperature by the configuration of LANDS?*

A. Islands and peninsulas are warmer than continents; bays and inland seas also tend to raise the mean temperature.

Q. *What effect has the SEA on temperature?*

A. In *warm climates* it tends to *diminish* the heat; in *cold climates* to *mitigate* the cold.

Q. *What effect have MOUNTAINS on temperature?*

A. Chains of mountains which ward off *cold* winds, raise temperature; but mountains which ward off *south* and *west* winds, lower it.

Q. *What effect has SOIL on temperature?*

A. A sandy soil which is dry, is warmer than a marshy soil which is wet, and subject to great evaporation.

For effects of forests on temperature, see p. 167.

Q. *Does all wind maintain the SAME velocity?*

A. The *velocity* of wind varies from 100 miles an hour in the *tornado*, to the scarcely perceptible motion of a *gentle breeze*.

## VERTICAL RAYS.

Q. *How does the rotation of the earth upon its axis affect the motion of the air?*

A. In two ways. 1st—As the earth moves round its axis, the air is left somewhat *behind*; and, therefore, seems to a body carried with the surface of the revolving earth, to be going in the opposite direction; and

2ndly—As the earth revolves, different portions of its surface are continually passing under the vertical rays of the sun.

Q. *When are the rays of the sun called "VERTICAL RAYS?"*

A. When the sun is in a *direct line* above any place, his rays are said to be "vertical" to that place.

Q. *Illustrate the manner in which the earth's surface passes under the vertical sun.*

A. Suppose some part of the brass meridian of a globe to represent the vertical sun; as you turn the globe round, *different parts* of its surface will pass under that part of the brass rim, in constant *succession*...

Q. *Why is it NOON-DAY to the place over which the SUN is VERTICAL?*

A. Because the sun is *half-way* between rising and setting to that place.

Q. \* *Show how this rotation of the earth affects the AIR.*

A. If we suppose some part of the brass meridian to be the vertical sun, the whole column of air *beneath* will be heated by the *noon-day rays*; that part which the sun has *left*, will become gradually *colder and colder*; and that part to which the sun is *approaching*, will grow constantly *warmer and warmer*.

Q. *Then there are THREE conditions of air about this spot?*

A. Yes; the air over the place, which has *passed* the meridian, is *cooling*; the air under the *vertical sun*, is the *hottest*; and the air, which is over the place *about to pass* under the meridian, is *increasing in heat*.

See fig. on p. 309. The column A (which the sun has passed) is cooling; B is under the vertical sun; and C is *increasing in heat*.

Q. *How does this VARIETY in the HEAT of AIR produce WIND?*

A. The air always seeks to *preserve a condition of equilibrium*; so, *cold air*

rushes into the place occupied by neighbouring warm air, and causes it to form an upward current. \*

Q. *Why does not the wind ALWAYS BLOW ONE way, following the direction of the SUN?*

A. Because the direction of the wind is subject to perpetual interruptions from *hills and valleys, deserts and seas, &c.*

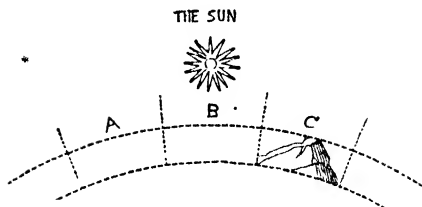
Q. *How can HILLS and MOUNTAINS ALTER the course of the WINDS?*

A. Suppose a wind (blowing from the north) comes to a mountain; as it cannot pass *through it*, it must either rush *back again*, or *fly off at one side*, (as a marble, when it strikes against a wall).

Q. *Do MOUNTAINS affect the wind in any OTHER way?*

A. Yes; many mountains are *capped with snow*, and the *warm air is condensed*, when it comes in contact with them; as soon as the *temperature of the air* is changed, the *direction* of its currents are altered also.

See figure on next page.



Suppose A B C to be *three columns of air*. A, the column of air which is *cooling down*; B, the column to which the *sun is vertical*; and C, the column which is *to be heated next*. In this case the *cold* air of A will rush towards B; because the air of B is *hotter* than that of A. But suppose now C to be a *snow-capped mountain*: as it comes under B, it preserves the air round it, at its low temperature still, and therefore checks for a time the ascent of the air in that direction.

Q. *How can the OCEAN affect the direction of the WIND?*

A. When the ocean rolls beneath the *vertical sun*, it is *not made so hot* as the *land* is; in consequence of which, the general direction of the wind is from tracts of *ocean* towards tracts of *land*.

Q. *Why is not the WATER of the sea made so HOT by the vertical sun, as the surface of the LAND?*

A. 1st—Because the *evaporation* of the sea is greater than that of land: and

2ndly—The *constant motion* of water prevents the increase of temperature at the surface.



Q. *Why does the EVAPORATION of the sea prevent its surface from being heated by the vertical sun ?*

A. Because its heat is *absorbed* in the generation of *vapour*, and carried off into the air.

Q. *Why does the MOTION of the sea prevent its surface from being heated by the vertical sun ?*

A. Because each portion *rolls away*, as soon as it becomes heated, and is succeeded by *another* ; and this constant motion prevents the *surface* of the sea from being *more* heated than the water *below* the surface.

Q. *How do CLOUDS affect the WIND ?*

A. As passing clouds screen the direct heat of the sun from the earth, they diminish the *rarefaction* of the air also : and this is another cause why neither the strength nor direction of the wind is *uniform*.

Q. *Do winds EVER blow REGULARLY ?*

A. Yes ; in those parts of the world, which present a large surface of water, as in the Atlantic and Pacific Oceans.

Q. *What are the regular winds, which blow over the ATLANTIC and PACIFIC Oceans, called ?*

A. They are called "trade winds."

They are called "trade" or "tread winds," because they uniformly pursue one tread or track.

Q. *What service are these winds to merchants?*

A. They are very convenient to merchants, who have to cross the ocean, inasmuch as they always blow uniformly in one direction.

Q. *In what DIRECTION do the trade winds blow?*

A. That in the *northern* hemisphere blows from the *north-east*: that in the *southern* hemisphere from the *south-east*.

Q. *Why do not these polar or trade winds blow from the FULL NORTH and SOUTH, directly towards the torrid zone?*

A. Because the poles, from which they flow, *move with less velocity* than the surface of the earth over which they pass in their progress towards the equator.

Q. *How does this difference of velocity affect the direction of the wind?*

A. In the same way as hedges, houses, or trees, (to a person in a carriage) seem to be running in an *opposite* direction.

As the circumference of the earth at the equator is *much larger* than the circumference of the earth at the poles; therefore, every spot of the earth's *equatorial* surface must move *much faster*, than the corresponding one at the poles.

Q. *Why do currents of air flow from the POLES to the EQUATOR?*

A. Because the air about the equator (being rarefied by the heat of the sun) *constantly ascends*, and thus gives way to the cold air from the poles.

Q. *Is there an UPPER as well as a LOWER CURRENT, in the atmosphere?*

A. Yes; the *upper* current of rarefied air is *from the equator to the poles*; being there condensed, it returns again to the *equator*, forming the *lower* current.

Q. *What effects are produced by the double current of air?*

A. 1st—The warming and cooling of the strata of air:

2ndly—The deposition of rain: and

3rdly—The formation and appearance of clouds.

Q. *How is the AIR affected by these opposing currents?*

A. As cold air returns from the poles to the equator, and hot air travels from the equator to the poles, both currents

are affected as they come into contact with each other.

Q. *How would these two opposite currents of air cause deposition of RAIN?*

A. The hot current from the equator being mixed with the cold current from the poles, are condensed, and compelled to part with some of their moisture in rain.

Q. *How are CLOUDS affected by the equatorial and polar currents of air?*

A. As the currents displace each other by any disturbing cause, *vapour* is added to or taken from the clouds, and produce a total change in the "face of the sky."

Q. *Why do the clouds vary almost incessantly even in the calmest day?*

A. In a great measure from some slight disturbance in the separate course of the equatorial and polar currents, whereby the upper current descends, and the lower one rises into the other.

Q. *Do trade winds blow from the north-east and south-east ALL the YEAR ROUND?*

A. Yes, *in the open sea*; that is, in the Atlantic and Pacific Oceans, for about 30 degrees each side of the equator.

Q. *What becomes of the north-easterly and south-easterly trade winds, when they approach the equator?*

A. They are lost in a region of *calms*, in which vessels are often detained for a considerable time.

Q. *Is this region of calms FIXED in its position?*

A. No; it shifts its place, according to the sun's distance, and position in regard to the *equator*: being sometimes entirely to the *north* of the equator, and occasionally reaching as far as 2 degrees *south* of it.

Q. *Do the TRADE WINDS blow uniformly from north-east and south-east in the INDIAN OCEAN?*

A. No; nor yet in those parts of the *Atlantic* and *Pacific* which verge on the continents.

Q. *How do the WINDS blow in the INDIAN OCEAN?*

A. From April to October a *south-west* wind prevails; but from October to April, a *north-east*.

Q. *What are these periodical currents of air (which affect the neighbourhood of the Arabian, Indian, and Chinese Seas) called?*

A. They are called MONSOONS.

The word monsoon is of Arabic derivation, *mausim* (a set time or season).

Q. *How far do the limits of the MONSOONS extend?*

A. From the African shore to the longitude of New Guinea; and *northward* as far as the parallel of latitude, which crosses the Loochoo Isles.

The Loochoo Isles are about 24° north latitude, and 30° east longitude.

Q. *Why do not the winds in the INDIAN OCEAN blow south-west from April to October, like the trade winds?*

A. Because the air of Arabia, Persia, India, and China *is so rarefied* by the enormous heat of their summer sun, that the colder air from the south rushes *towards these countries*, across the equator, producing a SOUTH-WEST wind.

Q. *To what distance does this SOUTH-WEST wind prevail?*

A. From 3 degrees south of the equator, to the shores of the Arabian, Indian, and Chinese Seas.

Q. *Why does the wind (in the INDIAN OCEAN) blow north-east from October to April?*

A. Because the *southern part of the torrid zone* is most heated when the sun is south of the equator: and the colder air from the north rushes towards the southern tropic producing a NORTH-EAST wind for six months of the year.

Q. *Are the monsoons as POWERFUL, as the trade winds?*

A. They are far *more* so, and very often amount to violent gales.

Q. *Why are MONSOONS more USEFUL to the mariners than the fixed TRADE WINDS?*

A. Because mariners are able to avail themselves of these periodic changes, to go in *one* direction during *one* half of the year, and to *return* in the *opposite* direction during the *other* half.

Q. *How is the change of the monsoons marked?*

A. By an interval of alternating calms and storms.

Q. *Have the winds in EUROPE any general directions throughout the year?*

A. We generally find that *easterly* winds prevail during the *spring* of the year; and *westerly* winds in the *summer* and *autumn*.

S-West winds are most frequent in July and August. N-East winds in January, March, April, May, and June; but *least* frequent in July, September, and December.

Q. *When are the WINDS in EUROPE generally the HIGHEST?*

A. The winds in December and January are generally the highest. Those in March and November the next; and those in August and September are the *least* boisterous.

Q. *Why are the winds of Europe generally HIGHEST in DECEMBER and JANUARY?*

A. Because the sun is *furthest south* in those months; and (as the heat in these northern regions rapidly *decreases*) the contrast between our temperature and that of the *torrid zone* is greater in December and January, than in any other two months throughout the year.

Q. *Why does this CONTRAST of heat increase the VIOLENCE of the WIND?*

A. Because the air always seeks to *preserve a state of equilibrium*; therefore,



the greater the contrast, the more violent will be the rush of air to *equalize* the two volumes.

Q. *Why are the winds in Europe generally most PLACID, during the months of SEPTEMBER and AUGUST?*

A. Because August and September are our *warmest months*, when we approach nearest to the heat of the torrid zone; therefore, the air (to and from the equator, moves with *less velocity* in our northern hemisphere in those two months than in any other.

Q. *Shew the goodness and wisdom of GOD, in this constant tendency of air to equilibrium.*

A. If the torrid zone were not tempered by cold air from the polar regions, it would become so hot, that no human being could endure it. If (on the other hand) the polar regions were never warmed by hot air from the torrid zone, they would soon become *insufferably cold*.

Q. *In what OTHER way does the mingling of the polar and equatorial atmosphere act BENEFICIALLY?*

A. In the *equatorial* regions, the

great abundance of vegetable life is productive of a very large amount of *oxygen*: In the colder regions, artificial *fires* and dense masses of *animal life*, produce large quantities of *carbonic acid*: The mingling of the polar and equatorial atmosphere assists in supplying each of these regions with the very gas, in which it would be otherwise defective.

Q. *How does the mingling of the POLAR and EQUATORIAL atmosphere serve to supply each region with the GAS it most requires?*

A. The *plants* of the EQUATORIAL regions require *carbonic acid*:—The *animals* of the COLDER regions require *oxygen*:—The currents of air from the *poles* carry *carbonic acid* to the equatorial *plants*; and the currents of air from the *equator* carry *oxygen* to the *animals* which abound nearer the *poles*.

Q. *Why are EAST WINDS in England generally COLD?*

A. Because they pass over the cold swampy plains of the North of Europe; and have no great breadth of ocean to flow over afterwards to warm them, before they reach our shores.

Q. *Why are EAST WINDS in England generally dry?*

A. Because they come over vast continents and very little ocean; in consequence of which, they have absorbed very little water.

Q. *How does this account for the drying power of the EAST winds?*

A. Being dry when they reach our island, they readily imbibe moisture from the air and clouds; and, therefore, bring dry weather.

Q. *Why are NORTH WINDS in England generally COLD?*

A. Because they come from the polar regions, over mountains of snow, and seas of ice.

Q. *Why are NORTH WINDS in England generally keen and drying?*

A. Because they come from regions colder than our own; and, being warmed by the heat of our island, absorb moisture wherever they find it.

Q. *Why are SOUTH WINDS generally WARM in England?*

A. Because they come over the

hot sandy deserts of Africa, which make them hot.

Q. *Why do SOUTH WINDS often bring us RAIN ?*

A. Because they are much *heated* by the hot sands of Africa ; and *imbibe water very plentifully*, as they pass over the Mediterranean Sea and British Channel.

Q. *How does this account for the RAINY character of SOUTH winds ?*

A. As soon as they reach our cold climate they are *condensed*, and can no longer hold all their vapour in suspension : in consequence of which, some of it is deposited as rain.

Q. *Why are WEST WINDS in England generally RAINY ?*

A. Because they come over the *Atlantic Ocean*, and are laden with *vapour* ; if, therefore, they meet with the least *chill*, some of the vapour is deposited as rain.

Q. *Why is a fine CLEAR DAY sometimes OVERCAST in a few minutes ?*

A. Because some *sudden change of temperature* has condensed the vapour of the air into clouds.

Q. *Why are CLOUDS sometimes DISSIPATED very suddenly?*

A. Because some *dry wind* (blowing over the clouds) *imbibes their moisture*, and carries it off in visible vapour.

Q. *Why do SOUTH-WEST winds bring us RAIN?*

A. Because they come from the *torrid zone*, and get *laden with vapour*, in their transit across the *ocean*. But, when they reach our northern island, (being condensed by cold) some of the vapour is precipitated in rain.

Q. *Why do NORTH-EAST winds RARELY bring RAIN?*

A. Because they come from a climate *colder than our own*, and their capacity for imbibing vapour is *increased*, when they reach our island; in consequence of which, north-east winds *dry the air*, dispel the clouds, and promote evaporation.

Q. *Why does WIND sometimes bring RAIN and sometimes FINE weather?*

A. If the wind be *colder than the clouds*, it will condense their vapour into rain: But if the wind be *warmer than the*

*clouds* it will *dissolve* them, and cause them to disappear.

Q. *Why are MARCH winds DRY?*

A. Because they generally blow from the east or north-east; and, therefore, sweep over the continent of Europe, and cross the cold waters of the German Ocean.

Q. *What is the USE of MARCH winds?*

A. They *dry* the soil, which is saturated with the floods of February,—break up the heavy clods,—and fit the land for the *seed* committed to it.

Q. *Why is it said, that “MARCH COMES IN like a LION?”*

A. Because it comes in with *blustering east winds*, so essential to dry the soil, lest it *rot the seeds* committed to it.

Q. *Why does “MARCH GO OUT like a LAMB?”*

A. Because the water (evaporated by the high winds) falls again in *showers*, to fertilize the earth; and these constant showers break the violence of the *winds*.

Q. *Why is it said, that “A bushel of MARCH DUST is worth a king’s ransom?”*

A. Because it indicates that there has

been a continuance of *dry weather*; and unless *March be dry*, the seed will rot in the wet soil.

Q. *Why is it said, "A DRY cold MARCH never BEGS BREAD?"*

A. Because the *dry cold winds* of March prepare the soil for *seeds*; which germinate, and produce fruit in the autumn.

Q. *It is said, that "A WET MARCH makes a SAD autumn." Explain the reason of this.*

A. If *March is wet*, so much seed *rots* in the ground, that the autumn crops are spoiled.

Q. *It is said, that "MARCH FLOWERS make NO summer BOWERS." Explain the reason of this.*

A. If the *spring be very mild*, vegetation gets too forward, and is *pinched* by succeeding *night-frosts*, so that the summer produces neither fruits nor flowers.

Q. *It is said, "A LATE SPRING makes a FRUITFUL YEAR." Explain the reason of this.*

A. If the vegetation of spring be *backward*, frosty nights will *do no harm*; because the fruits and flowers will not put forth their tender shoots, till the nights have become *too warm to injure them*.

Q. *Why is it said, that "APRIL SHOWERS bring MAY FLOWERS?"*

A. Because April showers supply the principal nourishment, on which seeds depend for their developement.

Before seeds can germinate, *three* things are essential: Darkness, Heat, and Moisture.

Q. *Does RAIN-water possess any fertilizing properties, BESIDES that of mere MOISTURE?*

A. Yes; rain-water contains an abundance of *carb'onic acid*, and a small quantity of *amm'onia*; to which much of its fertilizing power is attributed.

Ammonia is a compound of nitrogen and hydrogen. Common hartshorn is only ammonia and water.

Q. *Why has God made NOVEMBER a very RAINY month?*

A. Because rain hastens the *putrefaction* of the *fallen leaves*; and this makes the earth fertile.

Q. *Why is there MORE rain FROM SEPTEMBER to MARCH, than from March to September?*

A. Because the temperature of the air is *constantly decreasing*; on which account, its *capacity for holding vapour* is on the *decrease* also; and its vapour precipitated as rain..



## 326 MORNING AND EVENING BREEZE.

Q. *Why is there LESS rain from March to September, than from September to March ?*

A. Because the temperature of the air is constantly increasing; on which account, its capacity for holding vapour is on the increase, and very little is precipitated as rain.

Q. *Why is the rising sun in summer accompanied with a BREEZE ?*

A. Because the heat of the rising sun stops the radiation of heat from the earth, and warms its surface.

Q. *How does this warmth produce a BREEZE ?*

A. The air (resting on the earth's surface) being warmed by contact, ascends; and colder air rushing in to restore the balance, produces the morning breeze.

Q. *Why is there often an EVENING BREEZE during the summer months ?*

A. Because the earth radiates heat at sun-set, and the air is rapidly cooled down by contact: this condensation causes a motion in the air, called the evening breeze.

Q. *Why are TROPICAL ISLANDS subject to a sea-breeze every morning (i. e. a breeze blowing from the sea to the land ?)*

A. Because solar rays are unable to heat the surface of the *sea*, as they do that of the *earth*; therefore, the *air* resting on the *sea* is less *heated*, than the *air* resting on the *earth*; and the colder sea air blows *inland* to restore equilibrium.

Q. *Why is a land breeze generally less healthy than a sea breeze?*

A. Because it is frequently laden with exhalations from *putrefying animal* and *vegetable* substances.

Q. *Why is a sea breeze fresh and HEALTHY?*

A. Because it passes over the fresh sea, and is *not* laden with noxious exhalations.

It is particularly *healthy*, therefore, to walk on the *sea-beach* before ten o'clock in the morning; *but less so after sun-set.*

Q. *Why is there generally a fresh breeze from the SEA (in English watering places,) during the summer and autumn MORNINGS?*

A. Because *land* is *more heated* by the *sun*, than the *sea* is; in consequence of which, the cooler sea air glides *inland*, restoring equilibrium by pressing up the light hotter air.

Q. *Why does a sea breeze feel COOL?*

A. Because the sun cannot make the surface of the *sea* so hot as the *land*; therefore, the air which blows from the sea is *cooler* than the air of the *land*.

Q. *Why are tropical islands subject to a land breeze every EVENING (i. e. a breeze blowing from the land towards the sea)?*

A. Because the *surface of the land* cools down *faster* (after sunset), than the surface of the *sea*: in consequence of which, the air of the cold land is *condensed*, and flows into the warmer regions of the sea—causing a LAND BREEZE.

Q. *Why is the land breeze COOL?*

A. Because the surface of the land is cooled at sun-set *more quickly* than the surface of the sea; therefore, the air from the land feels cool.

Q. *Why is the temperature of islands more EQUABLE, than that of continents?*

A. Because the *water* around the island mitigates the extreme heat of summer, and *gives but* heat to diminish the extreme cold of winter.

Q. ISLANDS are WARMER in winter than continents. *Explain the reason of this.*

A. Unless the *sea be frozen* (which is rarely the case) it is warmer than the frozen land: and the warmth of the *sea* air helps to mitigate the intense cold of the *land* air.

Q. *Explain the cause of sea WAVES.*

A. The wind, pressing *unequally* on the surface of the sea, *depresses* one part more than another; every *depression* causes a corresponding *elevation*, and these undulations are called waves.

It must be remembered that waves have no other than a *vertical motion*, i. e. up and down. Any substance, as a buoy, floating on a wave, is merely elevated and depressed alternately; it does not otherwise change its place.

Q. *If waves are stationary, and only move up and down, why do they seem to advance towards the shore?*

A. This is an ocular deception. When a *corkscrew* is turned round, the thread appears to move forward; and the apparent *onward* motion of the waves of the sea is a similar delusion.

A wave is a *form*, and not a thing; the *form* advances, but not the *substance* of the waves.

Q. *What is the cause of BREAKERS?"*

A. The interference of rocks or rising banks in the sea with the regular form

of the wave, by which the "phase" of the curve is broken.

"The *phase* of the curve" is the outline or arc of the wave.

Q. *What causes the SPRAY of waves?*

A. The wind driving the surface of the water from the top of the wave, and scattering the small particles in all directions.

Q. *What is a TIDE?*

A. A wave of the *whole ocean*, which is elevated to a certain height, and then sinks after the manner of a common wave. The interval between the two positions forms a tide.

There are two tides in a lunar day, i. e. 24 hours, 49 minutes.

Q. *What is the CAUSE of tides?*

A. The principal cause is the *attraction of the moon*; which raises the waters of the ocean, as they come under her influence by the motion of the earth on its axis.

Q. *Why do we generally feel COLDER out-of-doors, than in-doors?*

A. \* Because the air is *always changing*; and before one portion has become heated by our body, another colder portion takes its place, and absorbs more heat.

Q. *Why is a ROOM (even without a fire) generally WARMER, than the OPEN AIR?*

A. Because the air in a room is *not subject to much change*, and soon becomes of the same temperature as our skin, after which it no longer feels cold.

Q. *How fast does wind travel?*

A. A gentle breeze goes at about the rate of 5 miles an hour. A high wind from 20 to 60. A hurricane from 80 to 100 miles an hour.

Q. *How is the VELOCITY of winds ascertained?*

A. By observing the velocity of the clouds; and by an instrument contrived for the purpose, called an Anemometer.

Pronounce An-e-mom'-e-ter. From two Greek words *ανεμος* (wind) and *μετρον* (a measure). This term is applied more frequently to an instrument which measures the *force* of wind.

Q. *How is the VELOCITY of the clouds ascertained?*

A. By observing the speed of their shadow along the ground: which is found (in a high wind) to vary from 20 to 60 miles an hour.

Q. *Why is there always a strong DRAUGHT through the KEYHOLE of a door?*

A. Because the air in the room we occupy is *warmer* than the air in the hall ; therefore, the air from the hall *rushes through the keyhole* into the room, and causes a draught.

Q. *Why is there always a strong DRAUGHT UNDER the door, and through the crevice on each side ?*

A. Because cold air rushes from the hall, to drive the warmer air up the chimney.

Q. *Why is there always a DRAUGHT through the WINDOW crevices ?*

A. Because the external air (being colder than the air of the room we occupy) rushes through the window crevices to drive the warm air up the chimney.

Q. *If you open the LOWER sash of a window there is more DRAUGHT, than if you open the UPPER sash. Explain the reason of this.*

A. If the lower sash be open, *cold external air* will rush freely into the room, and cause a great draught *inwards* ; but if the *upper* sash be open, the *heated air* of the room will rush out ; and (of course) there will be less draught *inwards*.

Cold air always flows to the spot occupied by warm air, and displaces it, because it is heavier. Both are drawn down to the earth, by its attraction, but the heavier cold air with the more force; it therefore occupies the lower position, and pushes the warm air upwards.

Q. *By which means is a ROOM better VENTILATED—By opening the upper or the lower sash?*

A. A room is better ventilated by opening the *upper sash*; because the hot vitiated air (which always ascends towards the ceiling) *can escape more easily*.

Q. *By which means is a HOT ROOM more quickly COOLED—By opening the upper or the lower sash?*

A. A hot room is cooled more quickly by opening the *lower sash*; because cold air can enter more freely at the *lower part* of the room, than at the *upper*.

Q. *Why does wind DRY damp LINEN?*

A. Because dry wind (like a dry sponge) imbibes the particles of vapour from the surface of linen, as fast as they are formed.

Q. *Why is the GALLERY of all public places HOTTER than the LOWER parts of the building?*

A. Because the heated air ascends; and all the cold air (which can enter



through the doors and windows), till it has become heated, *remains on the floor* of the room.

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## CHAPTER XXIII.

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### BAROMETER.

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Q. *What is a BAROMETER?*

A. A weather-glass, or instrument to measure the variations in the *weight* of the *air*.

BAROMETER is a compound of two Greek words, *Bapos* (weight) and *μετρον* (a measure). It is called a weather-glass, because changes of weather are indicated by its varying conditions.

Q. *What is a THERMOMETER?*

A. An instrument to show how *hot* or *cold* anything is.

THERMOMETER is a compound of two Greek words, *Θερμος* (heat) and *μετρον* (a measure).

Q. *What is the DIFFERENCE between a THERMOMETER and a BAROMETER?*

A. In a THERMOMETER the mercury is *sealed up from the air*; or falls, as the varying *temperature* of the air expands or contracts it: *but*

In a BAROMETER the column of mercury is left *exposed* (or open) to the air, at its *lower extremity*; and rises or falls, as the varying *weight* of the air presses more or less upon it.

Q. *If the mercury of the thermometer be SEALED UP from the air, how can the heat AFFECT it?*

A. The heat of the air passes *through the glass tube* into the mercury, causing the metal to expand and rise in the tube.

Q. *Why is the TUBE of a barometer left OPEN?*

A. That the air may *press upon* the exposed surface of the mercury: As this pressure varies, the mercury *rises or falls* in the tube.

The top of the tube must be a "*vacuum*;" otherwise the pressure of the external air upon the lower part of the column would not affect the mercury so freely.

Q. *For what PRACTICAL PURPOSES is the barometer used?*

A. 1st—To determine the height of mountains: and

2ndly—To indicate changes of the weather.

The barometer was invented by Toricelli, a pupil of Galileo, 1643.

Q. *How can a BAROMETER determine the HEIGHT of a mountain?*

A. As the *weight* of air decreases the *higher* we ascend, the mercury of a barometer will gradually *fall* and indicate the *height* of our ascent.

Q. *Does the density or weight of air decrease in any regular proportion?*

A. Yes; the density of air decreases upwards in a regular geometrical series.

Thus at an elevation of  $3\frac{1}{2}$  miles, the density of the air is only *half* what it is on the earth's surface; at 7 miles, only *one-fourth*; at  $10\frac{1}{2}$ , *one-eighth*; at 14 miles, *one-sixteenth*. Though the atmosphere probably extends 45 or 50 miles above the level of the sea, yet at an elevation of 20 miles, it has but little weight.

Q. *What causes the WEIGHT of AIR?*

A. The pressure of superincumbent strata. Thus in a pile of books, the lower volumes sustain the weight of those piled over them.

Q. *How can a barometer which measures the WEIGHT of air, be of service as a WEATHER glass?*

A. When air is filled with vapour, it is *lighter* than usual; and the column of mercury stands low. When air is dry and free from vapour, it is *heavier* than usual; and the mercury stands high. Thus the barometer (by shewing variations in the weight of the a

indicates when it is *moist*, and likely to rain or not.

Q. *Does the WEIGHT of the air VARY MUCH ?*

A. Yes; the atmosphere in England varies as much as *one-tenth part* more or less.

Q. *Of what USE is the BAROMETER to sailors ?*

A. It warns them to *prepare their ships*, before squalls come on.

Q. *How can a BAROMETER warn SAILORS to prepare their SHIPS ?*

A. As it indicates when *wind, rain, and storm* are at hand, the sailor can make his ship trim before they come upon him.

Q. *Are there any RULES, which can be depended on ?*

A. Yes; there are *ten special rules* to direct us how to know the changes of weather, by marking the mercury of a barometer.

Q. *Mention the 1st SPECIAL RULE with regard to the barometer.*

A. The barometer is *highest of all* during a *long frost*; and it generally rises *with a north-east wind*.

Q. *Why is the barometer HIGHEST of all during a long FROST?*

A. Because the air is exceedingly dry: and dry air causes the mercury of a barometer to rise.

Q. *Why does the barometer generally RISE with NORTH-EAST winds?*

A. Because NORTH-EAST winds make the air both *cold and dry*: and being both *condensed*, and *without vapour*, it is much heavier.

Q. *Mention the 2ND SPECIAL RULE with regard to the barometer.*

A. The barometer is *lowest of all* during a *thaw*, which follows a *long frost*: and it generally falls with SOUTH or WEST wind.

Q. *Why does the barometer fall LOWEST of all, at the BREAKING UP of a long FROST?*

A. Because the air (which had been much *dried* by the frost) *absorbs the moisture* of the fresh warm current of wind from the south or south-west: and becomes laden with vapour.

Q. *Why does the barometer fall very low with SOUTH and WEST winds?*

A. Because SOUTH and WEST winds come heavily *laden with vapour*: and *vaporized* air is lighter than *dry* air.

Q. *What effect has WIND on the mercury?*

A. The barometer is *high*, when the wind blows between the EAST and the NORTH. But it is *low*, when the wind blows between the SOUTH and WEST. •

Q. *What is the 3rd SPECIAL RULE with regard to the barometer?*

A. While the barometer stands above 30, the air must be very *dry*, or very *cold*, or perhaps *both*,—and *no rain* may be expected.

Q. *Why will there be NO RAIN, if the AIR be very DRY?*

A. Because *dry* air will *absorb moisture*, and not part with it in *rain*.

Q. *Why will there be NO RAIN, if the AIR be very COLD?*

A. Because it is *so much condensed*, that it has already parted with as much moisture as it can spare.

Q. *What is the 4th SPECIAL RULE with regard to the barometer?*

A. When the barometer stands *very*

## BAROMETER.

*low* indeed, there will never be *much* rain ; although a *fine day* will seldom occur at such times.

Q. *What kind of WEATHER is there likely to be, when the barometer is UNUSUALLY LOW ?*

A. *Short heavy showers, with sudden squalls of wind from the west.*

Q. *Why will there be VERY LITTLE RAIN, if the barometer is UNUSUALLY LOW ?*

A. Because the air must be very warm, or very moist, or perhaps both.

Q. *Why will there be little or no rain, if the AIR is very WARM ?*

A. Because warm air has a tendency to imbibe more moisture, and not to part with what it has.

Q. *Why will there be little or no rain, if the air be very MOIST, and the barometer very LOW ?*

A. Because rain will never fall (even tho' the air be saturated), till *cold air* has been introduced to *condense the vapour*: And, as soon as *cold air* has been introduced, the barometer will *rise* instantly.

Q. *Name the 5th SPECIAL RULE with regard to the barometer.*

A. In summer-time (after a long

continuance of fair weather) the barometer will *fall gradually* for 2 or 3 days before *rain* comes: But if the fall of the mercury is very *sudden*, a *thunder-storm* may be expected.

Q. *What is the 6th SPECIAL RULE with regard to the barometer?*

A. When the sky is cloudless, and seems to promise fair weather,—if the barometer is *low*, the face of the sky will soon be suddenly *overcast*.

Q. *What is the 7th SPECIAL RULE with regard to the barometer?*

A. Dark dense clouds will pass over *without rain*, when the barometer is *high*; but if the barometer be *low*, it will often rain *without* any appearance of clouds.

Q. *What is the 8th SPECIAL RULE with regard to the barometer?*

A. The *higher* the barometer, the greater the probability of *fair weather*.

Q. *Why is the barometer HIGH in FINE weather?*

A. Because the air in fine weather contains *very little vapour*. And the *drier*



the air, the *higher* does the mercury of the barometer rise.

Q. *What is the 9th SPECIAL RULE with regard to the barometer?*

A. When the mercury is in a *rising* state, *fine* weather is at hand: But when the mercury is in a *sinking* state, *foul* weather is near.

Q. *Why does the mercury RISE at the approach of FINE weather?*

A. Because the air is becoming more *dry*; and, therefore, its *pressure* is *increased*.

Q. *Why does the mercury SINK at the approach of FOUL weather?*

A. Because the air is *laden with vapour*, or *disturbed by wind*.

Q. *Why does VAPOUR in the air make the mercury SINK?*

A. Because vaporized air is *lighter than dry air*; and its *pressure* on the barometer *less*.

Q. *What is the 10th SPECIAL RULE with regard to the barometer?*

A. If (in frosty weather) it *begins to snow*, the barometer generally rises to 30; where it remains, so long as the

snow continues to fall: If, after this, the weather *clear up*, you may expect *very severe cold*.

Q. How can you know, if the MERCURY of the barometer be RISING?

A. When the top of the column is *convex* (i. e. higher in the *middle* than at the *sides*), the mercury is in a *rising state*.

Q. How can you tell if the MERCURY of the barometer be FALLING?

A. When the top of the column is *concave*, (i. e. *hollow* in the *middle*), the mercury is in a *falling state*.

Q. Why is the mercury CONVEX, when it is RISING?

A. Because the parts of the mercury in contact with the *tube* are delayed by the capillary attraction of the glass; in consequence of which, the *middle* part *rises faster* than the *sides*; and the surface is CONVEX.

Q. Why is the mercury CONCAVE, when it is FALLING?

A. Because the parts of the mercury in contact with the *tube* are delayed by

*capillary attraction* ; in consequence of which, the *middle part sinks faster than the sides* ; and the surface is *CONCAVE*.

Q. *What effect does a THUNDER-STORM produce on the weather ?*

A. It is generally *preceded by hot weather*, and *followed by cold showery weather*.

Q. *What effect does a SUDDEN CHANGE of temperature produce on the weather ?*

A. A great and sudden change (either from hot to cold, or from cold to hot) is generally followed by *rain within 24 hours*.

Q. *Why is a sudden CHANGE from HOT to COLD followed by rain ?*

A. Because *cold condenses the air* ; and some of its vapour is given off *in rain*.

Q. *Why is a sudden CHANGE from COLD to HOT followed by rain ?*

A. Because the air is quickly *saturated with moisture* ; but when *night comes on*, and *chills the temperature*, some of the abundant moisture is given off *in rain*.

Q. *Why is the air quickly SATURATED with MOISTURE, when HEAT rapidly succeeds to COLD?*

A. Because the evaporation (which was checked by the cold) is *carried on very rapidly* in consequence of the increase of temperature.

Q. *When does the barometer VARY MOST?*

A. In winter time.

Q. *Why does the barometer vary MORE in WINTER, than in SUMMER time?*

A. Because the *difference* of temperature between the torrid and temperate zones is much *greater* in winter than in summer; and produces a greater disturbance in the state of the air.

Q. *When does the barometer VARY LEAST?*

A. In summer time.

Q. *Why does the barometer vary LESS in SUMMER, than in WINTER?*

A. Because the temperature of our island in summer is more *nearly equal* to that of the torrid zone, and its state is *not so much* disturbed by interchange of currents.

Q. *Have HEAT and COLD any effect on the barometer?*

A. No, not of themselves; but as *cold* weather is generally *dry*, or accompanied with north-east winds, therefore the mercury *rises* in cold weather: And as warm weather is generally *moist*, and accompanied by south-west winds, therefore the mercury *sinks* in warm weather.

Q. *Why is the mercury of a barometer LOWER in the TORRID, than in the FRIGID zone?*

A. Because the warm air of the torrid zone contains much more *vapour*, than the condensed air of the frigid zone; and the *moister* the air, the *less* is its pressure.

Q. *In what MONTHS is the barometer HIGHEST?*

A. In May and August; then in June, March, September, and April.

Q. *In what MONTHS is the barometer LOWEST?*

A. In November and February; then in October, July, December, and January.

Q. *What are the DRIEST months?*

A. March and June; then May and August; then April and November.

Q. *What are the WETTEST months?*

A. October and February;

July and September; then January and December.

Q. *Why is there LESS wet from MARCH to AUGUST, than there is from August to March?*

A. Because the heat is *constantly increasing*; and the capacity of air to absorb and retain moisture increases likewise.

Q. *Why is there MORE wet from AUGUST to MARCH, than from March to August?*

A. Because the heat is *constantly decreasing*; and the capacity of air to retain moisture decreases also; so that (although it often rains) yet the air is always on the point of saturation.

Q. *What does a SUDDEN rise or fall of the barometer indicate?*

A. If the *rise* be sudden, fine weather will not continue long:

If the *fall* be sudden, foul weather will not continue long.

Q. *What sort of weather may we expect, if the barometer is very FLUCTUATING?*

A. If the mercury fluctuates much, the weather will be very *changeable* and *unsettled*.

## THE FALL OF THE BAROMETER.

In very *hot* weather, the fall of the mercury denotes *thunder*; otherwise, the sudden falling of the barometer denotes high wind.

In *frosty* weather, the fall of the barometer denotes *thaw*.

If *wet* weather happens soon after the fall of the barometer, expect but *little* of it.

In *wet* weather, if the barometer falls, expect much wet.

In *fair* weather, if the barometer falls and *remains* low, expect much wet in a few days, and probably *wind*.

N. B. The barometer sinks lowest of all for wind and rain together; next to that for wind, (except it be an east or north-east wind).

## RISE OF THE BAROMETER.

In *winter*, the rise of the barometer presages *frost*.

In *frosty* weather, the rise of the barometer presages *snow*.

If *fair* weather happens soon after the rise of the barometer, expect but *little* of it.

In *wet* weather, if the mercury rises high and *remains* so, expect continued *fine weather* in a day or two.

In *wet* weather, if the mercury rises suddenly very high, *fine weather* will not last long.

N. B. The barometer rises highest of all for north and east wind; for all *other* winds it sinks.

## THE BAROMETER UNSETTLED.

If the motion of the mercury be *unsettled*, expect unsettled weather.

If it stand at "MUCH RAIN" and rise to "CHANGEABLE," expect *fair weather of short continuance*.

If it stand at "FAIR" and fall to "CHANGEABLE," expect *foul weather*.

N. B. Its motion *upwards*, indicates the approach of *fine weather*; its motion *downwards*, indicates the approach of *foul weather*.

## CHAPTER XXIV.

## SNOW. HAIL. RAIN.

A. The condensed vapour of the air *frozen*, and precipitated to the earth.

Q. *What is the CAUSE of SNOW?*

A. When the air is nearly saturated with vapour, and condensed by a current of air *below freezing point*, some of the vapour is precipitated in a crystalline form as snow.

A few years ago, some fishermen (who wintered at Nova-Zembla), after they had been shut up in a hut for several days, *opened the window*; and the cold external air rushing in, instantly condensed the air of the hut, and its vapour fell on the floor *in a shower of snow*.

Q. *Why does SNOW fall in WINTER?*

A. Because the sun's rays are too *oblique* to heat the surface of the earth; and (as the earth has but little heat to radiate into the air) the air is very cold.

Q. *What is the cause of SLEET?*

A. When flakes of snow (in their descent) pass through a bed of air *above*



*freezing point*, they partially melt; and fall to the earth as half-melted snow, or sleet.

Q. *What is the USE of SNOW?*

A. To keep the earth *warm*, and to *nourish* it.

Q. *Why does snow keep the EARTH WARM?*

A. Because it is a very *bad conductor*; in consequence of which, when the earth is covered with snow, its temperature very rarely descends *below freezing point*, even when the air is 15 or 20 degrees colder.

Q. *Tell me the words of the PSALMIST (cxlvii. 16) respecting snow; and explain what he means.*

A. The Psalmist says—"The Lord giveth snow like wool;" and he means, not only that snow is *white like wool*, but that it is also *warm as wool*.

Q. *Why is WOOL WARM?*

A. Because *air* is entangled among the fibres of the wool: and air is a very *bad conductor*.

Q. *Why is SNOW WARM?*

A. Because *air* is entangled among the crystals of the snow; and air is a very *bad conductor*.

Q. *Why does SNOW NOURISH the earth?*

A. Because it supplies *moisture* containing carbonic acid; which penetrates slowly into the soil, and insinuates itself through every clod, ridge, and furrow, when the snow melts.

Q. *Why is there NO SNOW in SUMMER time?*

A. Because the *heat of the earth* melts it in its descent, and prevents it from reaching the surface of the earth.

Q. *Why are some MOUNTAINS ALWAYS COVERED with SNOW?*

A. 1st—Because the *air* on a high mountain is more *rarefied*; and as rarefied air retains much heat in a latent state, it abstracts heat from adjacent bodies more rapidly than condensed air would: and

2ndly—Mountain tops are not *surrounded by earth*, to radiate heat into the air; and, therefore, the snow is *not melted* in its descent, but falls on the mountain and lies there.

Q. *Why is SNOW WHITE?*

A. Because it is formed of an infinite

number of very minute crystals and prisms, which reflect all the component rays of which white light consists.

The same answer applies to salt, loaf sugar, &c. (*see p. 419*).

Q. *What is HAIL?*

A. Rain, which has passed in its descent *through a cold bed of air*, and has been frozen into ice.

Q. *What makes ONE bed of air COLDER than another?*

A. The causes are not perfectly known; *electrical action* is most probably among them.

Q. *Why is HAIL frequently accompanied with THUNDER and LIGHTNING?*

A. 1st—Because the *congelation of water into hail* disturbs the electricity of the air: and

2ndly—The *friction* (produced by the fall of hail) may possibly excite it still more.

Q. *Why does HAIL fall generally in SUMMER and AUTUMN?*

A. 1st—Because the air is *more highly electrified* in summer and autumn, than in winter and spring: and

## RAIN.

2ndly—The vapours in summer and autumn (being rarefied) ascend to more elevated regions, which are *colder* than those nearer the earth.

Q. *What two things are essential to cause HAIL?*

A. Two strata of clouds having opposite electricities, and two currents of wind. The lower cloud containing resinous electricity, is the one precipitated in hail.

Q. *What is RAIN?*

A. The vapour of the clouds or air condensed, and precipitated to the earth.

Q. *When is the vapour of the air or clouds PRECIPITATED in hail, rain, or snow?*

A. When the air is saturated with vapour, and a cold current condenses it, it is then no longer able to hold all its vapour in solution, and some of it falls as rain.

Q. *Why does RAIN fall in DROPS?*

A. Because the vapoury particles in their descent attract each other; and those which are sufficiently near unite, and form into drops.

Q. *Why does not the COLD of NIGHT ALWAYS cause rain ?*

A. Because the air is not always near saturation : And unless this be the case, it will be able to hold its vapour in solution, even after it has been condensed by the chilly night.

Q. *Why does a PASSING CLOUD often drop RAIN ?*

A. Because it comes in contact with cold air, which *chills it* ; and its vapour being condensed, falls to the earth as rain.

Q. *Why are RAIN-DROPS sometimes much LARGER, than at OTHER times ?*

A. Because the rain-cloud is floating near the earth ; when this is the case, the drops are large, because such a cloud is much more *dense*, than one more elevated.

The size of the rain-drop is also increased, according to the *rapidity* with which the vapours are condensed.

Q. *Does not WIND sometimes INCREASE the SIZE of rain-drops ?*

A. Yes ; by blowing two or more drops into one.

Q. *Why do CLOUDS FALL in RAINY weather ?*

A. 1st—Because they are *heavy* with abundant vapour : and

2ndly—The density of the air being *diminished*, is less able to buoy the clouds up.

Q. *How do you KNOW, that the DENSITY of the air is DIMINISHED in RAINY weather ?*

A. Because the mercury of a barometer *falls*.

Q. *Why is RAIN-WATER more FERTILIZING, than PUMP-water ?*

A. 1st—Because it contains more carbonic acid : and

2ndly—It contains a small quantity of *ammonia*, with which it supplies the young plants.

Q. *Why does RAIN PURIFY the AIR ?*

A. 1st—Because it *dissolves* the *noxious exhalations* collected in the air, as it falls.

2ndly—It mixes the air of the *upper* regions with that of the *lower regions* : and

3rdly—It *washes the earth*, and sets in motion the stagnant contents of sewers and ditches.

## 356 EFFECTS OF WET WEATHER.

Q. *Why are MOUNTAINOUS countries more RAINY, than flat ones ?*

A. Because the air (striking against the sides of the mountains) is *carried up the inclined plane*, and brought in contact with the *cold air* of the higher regions : in consequence of which, its vapour is *condensed*, and deposited in rain.

Q. *Why does a SPONGE SWELL, when it is WETTED ?*

A. Because the water penetrates the pores of the sponge by capillary attraction, and drives the particles further from each other - in consequence of which, bulk of the sponge is greatly increased.

Q. *Why do FIDDLE-strings snap in WET weather ?*

A. Because the moisture of the air (penetrating the strings) causes them to *swell* ; and (as the cords *thicken*) their *tension is increased*, and the strings snap.

Q. *Why does PAPER PUCKER, when it is WETTED ?*

A. Because the moisture is absorbed *unequally* by the paper, and some parts are more enlarged than others ; in con-

sequence of which, the paper *blisters* or *puckers*.

Q. *Why do the weather-toys (called CAP'UCHINS) lift a cowl over the figures in wet weather, and remove it in dry?*

A. Because the cowl of the cap'uchin is attached to a *piece of cat-gut* in such a manner, that when the cat-gut is *shortened by moisture*, it pulls the cowl up; but in *dry weather*, the string is *loosened*, and the cowl falls down by its own weight.

Q. *Why do the weather-toys (called MAN'ICULI) twist the man out in wet weather and pull him in in dry weather?*

A. Because the two figures are attached to a *piece of cat-gut* in such a manner, that when the cat-gut is *moist* it twists the *man out*; but when it is *loosened*, the figures turn in the opposite direction.

Q. *Why are WET STOCKINGS DIFFICULT to PULL ON?*

A. 1st—Because the moisture penetrates the threads of the stockings, and causes them to *shrink in size*: and



2ndly—Because the moisture causes the stockings to adhere to our feet.

Q. *What are the MOST RAINY towns in ENGLAND?*

A. Keswick (in Cumberland); and then Kendal, (a market town in Westmoreland.)

In Keswick, about 63 inches of rain fall in a year. In Kendal 58; Manchester, 38; Liverpool, 34; Dublin and Cambridge, 25; Lincoln, 24; London, 21; and in Paris, only 18.

Q. *In which PART of the DAY does the MOST RAIN fall?*

A. More rain falls by *night*, than by *day*; because the cold night *condenses* *air*, and diminishes its capacity for holding vapour in solution.

Q. *Does more rain fall in SUMMER or in WINTER?*

A. There are *more rainy days* from September to March: but *heavier* rains between March and September.

Q. *Why are there MORE RAINY DAYS from September to March, than from March to September?*

A. Because the temperature of the air is *constantly decreasing*; and as its capacity for holding vapour decreases also,

it is frequently obliged to part with some of its vapour in rain.

Q. *In what PART of the WORLD does RAIN fall MOST ABUNDANTLY?*

A. Near the *equator*; and the quantity of rain *decreases*, as we approach the *poles*.

There are fewer rainy *days*, altho' more *rain* actually falls during the wet season of the equator—than falls in 12 months at any other part of the globe.

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## CHAPTER XXV.

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# WATER.

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Q. *Of what is WATER composed?*

A. Of two *gases*, oxygen and hydrogen.

In 9lbs. of water—8 are oxygen, and 1 is hydrogen.

Q. *Why is WATER FLUID?*

A. Because its particles are kept separate by *latent heat*: When a certain quantity of this latent heat is driven out, *water becomes solid*, and is called ice.

By increasing its *latent heat*, the particles of water are again subdivided into *invisible steam*.

Q. *Why is PUMP water called "HARD water?"*

A. Because it is laden with foreign matters, and will not readily *dissolve substances* immersed in it.

Q. *What makes PUMP-water HARD?*

A. When it filters through the earth, it becomes impregnated with the *sulphate and carbonate of lime*, as well as with many other principles derived from the *earths and minerals* with which it comes in contact.

Q. *What is the cause of MINERAL SPRINGS?*

A. When water trickles through the ground, it dissolves some of the substances with which it comes in contact; if these substances are metallic, the water will partake of their mineral character.

Some water is imbued with *lime*; some with *salt*, &c. &c.

Q. *Why is it difficult to WASH our HANDS clean with HARD water?*

A. Because the *soda of the soap* combines with the *sulphuric acid* of the salts of hard water,—and the *oil of the soap* with the *lime*—and floats in flakes on the top of the water.

N. B. Sulphate of lime consists of sulphuric acid and lime.

Q. *Why is it difficult to wash in SALT WATER?*

A. Because it contains *saline matters*, which deprive the water of a portion of its solvent power.

Q. *What is the cause of PETRIFACTIONS?*

A. While water flows underground, its impurities are held in solution by the presence of carbonic acid; but when the stream reaches the open air, its carbonic acid escapes, and these impurities are precipitated on various substances lying in the course of the stream.

These impurities are especially carbonate of lime and iron.

Q. *Why does a BLACK HAT turn RED at the SEA SIDE?*

A. Because chloride of iron is formed by chemical action, between the components of iron and the chlorine, existing in the dye and sea air; the chloride of iron afterwards decomposes, and forms peroxide of iron, which causes the rusty hue.

Q. *Of what is SOAP made?*

A. Of kelp (or the ashes of sea-weed dried and burnt in a pit) mixed with oil or fat.

YELLOW SOAP is made of whale-oil, soda, and resin. SOFT SOAP of oil and potash. HARD SOAP of oil and soda. I a

Q. *Why does WATER CLEAN dirty LINEN ?*

A. Because it *dissolves* the stains, as it would dissolve salt.

Q. *Why does SOAP greatly INCREASE the cleansing power of water ?*

A. Because many stains are of a *greasy nature* ; and soap has the power of *uniting with greasy matters*, and rendering them soluble in water.

Q. *Why is RAIN WATER SOFT ?*

A. Because it is not impregnated with *earths and minerals*.

Q. *Why is it MORE EASY to WASH with SOFT water, than with hard ?*

A. Because soft water unites freely with soap, and *dissolves* it ; instead of decomposing it, as hard water does.

Q. *Why do WOOD ASHES make HARD water SOFT ?*

A. 1st—A double decomposition takes place : the carbonate of potassa in the ashes, and the sulphate of lime in the water unite, and form into sulphate of potassa and carbonate of lime.

2ndly—Wood ashes convert some of the soluble salts of water into insoluble,

and throw them down as a sediment; by which means the water is rendered more pure.

Q. *Why has RAIN water such an UNPLEASANT SMELL, when collected in a tub or tank?*

A. Because it is impregnated with *decomposed* organic matters, washed from roofs, trees, or the casks in which it is collected.

Q. *Why does WATER MELT SUGAR and SALT?*

A. Because very minute particles of water insinuate themselves into the *pores* of the sugar, by capillary attraction: and unite with the minute atoms of the sugar.

Q. *Why does melted SUGAR or SALT give a FLAVOUR to water?*

A. Because the sugar or salt (being disunited into very minute particles) *floats* about the water, and mixes with it intimately.

Q. *Why does HOT water melt sugar and salt QUICKER than COLD water?*

A. Because the *heat* (entering the pores of the sugar or salt) opens a passage for the water.

Q. *Why is SEA-water brackish ?*

A. Because it holds in solution a quantity of *saline matter*, of which common salt is the principal ingredient.

According to a recent analysis, 1000 grains of sea-water from the British Channel, contained 27 grains of common salt and about 8 grains of other saline matter.

Q. *Why is NOT RAIN-water SALT, although most of it is evaporated from the SEA ?*

A. Because saline matter will not *evaporate*; and, therefore, when sea-water is turned into vapour, its salt is left behind.

Q. *Why does STAGNANT water PUTREFY ?*

A. Because leaves, plants, insects, &c. are decomposed in it.

Q. *Why is STAGNANT water full of WORMS, INSECTS, &c. ?*

A. Because numberless insects *lay their eggs* in the leaves and plants floating on the surface; these eggs are soon hatched, and produce swarms of worms and insects.

Q. *Why is FLOWING water FREE from IMPURITIES ?*

A. Because its currents carry away all *contaminating substances* to the sea,

as fast as they appear in it; and there they are *diffused* through so *large a mass of fluid*, that they become inappreciable.

Q. *Why does* RUNNING water OSCILLATE and WHIRL *in its current?*

A. 1st—Because it *strikes* against the *banks*, and is perpetually diverted from its forward motion: and

2ndly—Because the *centre* of a river flows faster than its sides.

Q. *Why do the SIDES of a river flow more TARDILY, than its CENTRE?*

A. Because they *rub* against the *banks*, and are delayed in their current by friction.

Q. *Why does* SOAPY water BUBBLE?

A. Because soap makes *water tenacious*; and prevents the bubbles from *bursting*, as soon as they are formed.

Q. *Why will not water bubble WITHOUT SOAP?*

A. Because it is not tenacious enough to hold together the *bubbles* that are formed.

Q. *When* SOAP-BUBBLES are blown from a pipe, *why do they ASCEND?*

A. Because they are *filled with the warm breath*, which is lighter than air.



## CHAPTER XXVI.

ICE.

Q. *What is ICE?*

A. FROZEN WATER. When the temperature of the air is reduced to 32 degrees, water will no longer remain in a *fluid state*.

Q. *Why is SOLID ICE LIGHTER than WATER?*

A. Because water *expands* by freezing; and as its *bulk* is *increased*, its *gravity* must be *less*.

Nine cubic inches of water become *ten* when frozen.

Q. *Why do EWERS BREAK in a FROSTY NIGHT?*

A. Because the water in them *freezes*; and (*expanding* by frost) bursts the ewers to make room for its increased volume.

Q. *Why does it not expand UPWARDS (like boiling water) and RUN OVER?*

A. Because the *surface* is frozen first; and the frozen surface acts as a *plug*, which is more difficult to burst, than the earthen ewer itself.

Q. *Why do* TILES, STONES, *and* ROCKS, *often* SPLIT *in* winter?

A. Because the moisture in them freezes; and (expanding by frost) splits the solid mass.

Q. *In* winter time, FOOT-MARKS *and* WHEEL-RUTS *are* often covered with an icy NET-WORK, through the interstices of which the soil is clearly seen,—WHY does the water freeze in NET-WORK?

A. Because it freezes first at the sides of the foot-prints: other crystals gradually shoot across, and would cover the whole surface, if the earth did not absorb the water, before it had time to freeze.

Q. *In* winter time, these FOOT-MARKS *and* WHEEL-RUTS *are* sometimes covered with a perfect SHEET of ice, and not an icy net-work,—Why is THIS?

A. Because the air is colder, and the earth harder, than in the former case; in consequence of which, the entire surface of the foot-print is frozen over, before the earth has had time to absorb the water.

Q. *Why* is not the ice SOLID in these ruts?—WHY is there only a very thin FILM or NET-WORK of ice?

### 368 WATER-PIPES BURST FROM FROST.

A. Because the earth *absorbs most of the water*, and leaves only the icy *film behind*.

Q. *Why do WATER-PIPES frequently BURST in FROSTY weather?*

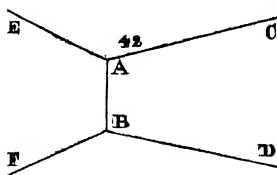
A. Because the water in them *freezes*; and (*expanding by frost*) bursts the pipes, to make room for its increased volume.

Q. *Does not water expand by HEAT, as well as by COLD?*

A. Yes; it expands as soon as it is more than 40 degrees, *till it boils*; after which time, it flies off in steam.

Freezing water, 32°.

212° Boiling water.



Here A B measures the bulk of a portion of water at 40 degrees.

It goes on increasing in bulk to C D, when it boils.

It also goes on increasing in bulk to E F, when it freezes.

Q. *WHEN does WATER begin to EXPAND from cold?*

A. When it is reduced to 40 degrees. It is wisely ordained by God that water

shall be an *exception* to a very general rule, it *contracts* till it is reduced to 40 degrees, and then it *expands till it freezes*.

The general rule is this—That cold *condenses* and *contracts* the volume of nearly every thing ; but water is *not contracted* by cold after it has reached 40 degrees.

Q. WHY does water expand when it freezes ?

A. Because it is converted into *solid crystals*, which *do not fit so closely* as the particles of water did.

Q. Why is the BOTTOM of a river SELDOM FROZEN ?

A. Because water, when it becomes colder than 40 degrees, *ascends* to the surface ; and (if it freezes) *floats there*, till it is melted.

Q. Show the WISDOM of GOD in this wonderful exception to a general law.

A. If ice were *heavier than water*, it would *sink* ; and a river would soon become a *solid block of ice*, which could never be dissolved.

Q. Why does not ICE on the SURFACE of a river CHILL the water BENEATH, and freeze it ?

A. 1st—Because water is a *very bad conductor*, and is heated or chilled by CONVECTION only : and

2ndly—The ice on the surface acts as a *shield*, to prevent cold air from *penetrating through the river*, to freeze the water below the surface.

Q. *Why does WATER FREEZE at the SURFACE first?*

A. Because the surface is in *contact with the air*, and the air carries away its heat.

Q. *Why does the coat of ice grow THICKER and THICKER, if the frost CONTINUES?*

A. Because the *heat* of the water (immediately below the frozen surface) *passes through the pores of the ice* into the cold air.

Q. *Why are not WHOLE RIVERS FROZEN (layer by layer), till they become solid ice?*

A. Because water is so *slow* a conductor, that our frosts never continue *long enough*, to convert a whole river into a solid mass of ice.

Q. *Why does not RUNNING water freeze so FAST as STILL water?*

A. Because the rapid motion of the current prevents the *crystals* from forming into a continuous surface.

Q. When *RUNNING water* is FROZEN, why is the ICE generally very ROUGH?

A. Because little flakes of ice are first formed and carried down the stream, till they meet some *obstacle* to stop them; then *other* flakes of ice (impinging against them) are arrested in like manner; and the *edges* of the different flakes *overlap*-*ping* each other, make the surface *rough*.

Q. Why do *SOME parts* of a river FREEZE LESS than others?

A. Because *springs* issue from the bottom; and, bubbling upwards, *thaw* the ice, or make it thin.

Q. When persons FALL into a river in winter, why does the WATER feel comparatively WARM?

A. Because the *frosty air* is at least 10 or 12 degrees *colder* than the water.

The frozen river below its surface is at least 40°; but the air 32°, or even less.

Q. Why is SHALLOW water FROZEN more QUICKLY than DEEP water?

A. Because the *whole volume* of water must be cooled to 40 degrees, before its *surface* can be frozen: and it takes a longer time to cool down a *deep* bed of water, than a *shallow* one.

Q. Why is

A. 1st—Because the *mass of water is so great*, that it requires a very long time to cool the whole volume down to 40 degrees :

2ndly—The *ebb and flow* of the sea interfere with the cooling influence of the air : and

3rdly—*Salt* water never freezes, till the surface is cooled down 4 or 5 degrees below the freezing point of fresh water.

Q. *Why do some LAKES RARELY (if ever) FREEZE ?*

A. 1st—Because they are *very deep* and

2ndly—Because their water is supplied by *springs*, which bubble from the bottom

Q. *Why does the DEPTH of water RETARD its freezing ?*

A. Because the *whole volume of water* must be reduced to 40 degrees, before the surface will freeze : and the *deeper* the water, the *longer* it will be before the whole volume is thus reduced.

Q. *Why do SPRINGS at the bottom of a lake PREVENT its freezing ?*

A. Because they continually send forth *fresh water*, which prevents the lake

from being reduced to the necessary degree of coldness.

Q. *It is COLDER in a THAW, than in a FROST. Explain the reason of this.*

A. When frozen water is *thawed*, it *absorbs* heat from the *air*, &c. to melt the ice: in consequence of which, the heat of the air is greatly reduced. •

Q. *It is WARMER in a FROST, than in a THAW. Explain the reason of this.*

A. When water *freezes*, it gives out *latent heat*; and as much heat is liberated from the water into the atmosphere, the air feels *warmer*. (See N. B. p. 32.)

Q. SALT DISSOLVES ICE. *Explain the reason of this.*

A. Water freezes at  $32^{\circ}$ , but *salt* and water will not freeze till the *air* is 4 or 5 degrees *colder*; if, therefore, salt be added to frozen water, it dissolves the ice.

Q. *Will anything DISSOLVE ICE besides SALT?*

A. Yes; any *acid*, such as sulphuric acid, nitric acid, &c.

Anything which has a very strong affinity for water will liquify ice.



Q. *Why is a mixture of SALT and SNOW, colder than SNOW itself?*

A. Because salt dissolves the crystals of snow into a fluid: And whenever a solid is converted into a fluid, *heat is absorbed*, and the cold made more intense.

Q. *Why does FROST make the EARTH CRACK?*

A. Because the water absorbed in warm weather, expanding by the frost, thrusts the particles of earth apart from each other, and leaves a chink or crack between.

Q. *Show the WISDOM of God in this arrangement.*

A. These cracks in the earth let in air, dew, rain, and many gases favourable to vegetation.

Q. *Why does the EARTH CRUMBLE in SPRING?*

A. Because the ice of the clods dissolves; and the particles of earth (thrust apart by the frost) being left unsupported, tumble into minute parts, as soon their cement of ice is dissolved.

Q. *Why does MORTAR CRUMBLE away in FROST?*

A. Because it was not dried in the

*warm weather* ; therefore, its moisture *freezes, expands*, and thrusts the particles away from each other ; but when the frost breaks up, the *water condenses*, and leaves the mortar full of cracks and chinks.

Q. *Why does STUCCO PEEL from a WALL in FROSTY weather ?*

A. Because the stucco was not *dried in the warm weather* ; therefore, its moisture *freezes, expands*, and thrusts the particles away from the wall ; but, as soon as the water condenses again from a thaw, the stucco (being unsupported) *falls by its own weight*.

Q. *Why cannot BRICKLAYERS and PLASTERERS work in frosty weather ?*

A. Because *frost expands mortar*, and causes the bricks and plaster to *start from their position*.

Q. *Why do BRICKLAYERS COVER their work with STRAW in spring and autumn ?*

A. Because straw is a non-conductor ; and prevents the mortar of their new work from *freezing*, during the cold nights of spring and autumn.

Q. *Why are WATER-PIPES often covered with STRAW in winter-time?*

A. Because straw (being a non-conductor) prevents the *water of the pipes from freezing*, and bursting the pipes.

Q. *Why are delicate TREES covered with STRAW in WINTER?*

A. Because straw (being a non-conductor) prevents the *sap of the tree* from being frozen.

Q. *Can WATER be FROZEN in any way BESIDES by frosty weather?*

A. Yes; in very many ways. For example—a bottle of water wrapped in cotton, and frequently *wetted with ether*, will soon freeze.

Q. *Why would WATER FREEZE if a bottle were kept constantly wetted with ETHER?*

A. Because *evaporation* would carry off the heat of the water, and reduce it to *freezing point*.

Q. *Why does WATER freeze under the RECEIVER of an AIR pump, when ether is present and the air exhausted?*

A. Because *evaporation* is very greatly increased by the *diminution of atmospheric*

*pressure* ; and the ether evaporating very rapidly, produces sufficient cold to freeze the water.

## FREEZING MIXTURES.

1. If nitre be dissolved in water, the heat of the liquid will be reduced 16 degrees.

2. If 5 oz. of nitre, and 5 of sal-ammoniac (both finely powdered) be dissolved in 19 oz. of water, the heat of the liquid will be reduced 40 degrees.

3. If 3 lbs. of snow be added to 1 lb. of salt, the mixture will fall to 0° (or 32 degrees below freezing point.)

The two following are the coldest mixtures yet known :—

1. Mix 3 lbs. of muriate of lime with 1 lb. of snow.

2. Mix 5 lbs. of diluted sulphuric acid with 4 lbs. of snow.

Ice may be made in a *red-hot* vessel thus. Heat a platinum vessel red hot, pour into it a little water—then some liquid sulphurous acid ; turn the vessel over, and ice will come out. The reason is this, the sulphurous acid so suddenly evaporates from the heat of the vessel, that the water is frozen.

Q. *Why is it more easy to swim in the sea, than in a river ?*

A. Because the *specific gravity* of salt water is *greater*, than that of fresh ; and, therefore, it *buoys* up the swimmer better. •

Q. *How do cooks ascertain, if their BRINE be SALT ENOUGH for pickling ?*

A. They put an egg into their brine. If the egg *sink*, the brine is *not strong enough* ; if the egg *float*, it is.

Q. *Why will an EGG SINK, if the brine be NOT STRONG enough for pickling ?*

A. Because the egg will be the *heavier*: but if as much *salt* be added as the water can dissolve, the brine will buoy up the egg, and cause it to float.

Q. WHY will an EGG FLOAT in strong BRINE, and not in water ?

A. Because the specific gravity of *salt and water* is greater, than that of *water only*.

Q. Why do persons SINK in water, when they are UNSKILFUL SWIMMERS ?

A. Because they struggle to keep their *head out of water*.

Q. Explain how this is.

A. When our head is thrown back boldly into the water, our mouth is kept *above the surface*, and we are able to breathe:

But when the head is kept *above the surface* of the water, the chin and mouth sink *beneath* it, and the swimmer is suffocated.

This may be illustrated thus:—If a piece of wood be of such specific gravity, that only *two square inches* can float out of water; it is manifest, that if two *other* inches are raised out, the two *former* inches must be plunged in. The body (in floating) resembles this piece of wood—If two square inches of our *face* float out of the water, we can breathe; but if part of the *back* and *crown*

of our head be forcibly raised above the surface, a proportional quantity of our face must be plunged in; and our mouth becomes covered with water.

Q. *Why can QUADRUPEDS swim MORE EASILY than MAN?*

A. 1st—Because the *trunk* of quadrupeds is *lighter* than water; and this is the greatest part of them: and

2ndly—The *position* of a beast (when swimming) is a *natural* one.

Q. *Why is it MORE DIFFICULT for a MAN to swim, than for a BEAST?*

A. 1st—Because his body is more *heavy* in proportion, than that of a *beast*: and

2ndly—The *position* and muscular action of a *man* (when swimming) differ greatly from his ordinary habits; but beasts swim in their *ordinary* position.

Q. *Why can FAT men SWIM more EASILY than SPARE men?*

A. Because *fat* is *lighter* than water; and the *fatter* a man is, the more *buoyant* will he be.

Q. *How are FISHES able to ASCEND to the SURFACE of water?*

A. Fishes have an *air-bladder* near

the abdomen; when this bladder is *filled with air*, the fish increases in size; and (being lighter) ascends through the water to its surface.

Q. *How are fishes able to DIVE in a minute to the BOTTOM of a stream?*

A. They *expel the air* from the air-bladder; in consequence of which, their *size is diminished*, and they sink instantly.

## CHAPTER XXVII.

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## LIGHT.

Q. *What is LIGHT?*

A. Rapid undulations of a fluid called the *luminous ether*, made sensible to the eye, by striking on the optic nerve. (*See p. 48*).

The several particles of which air is composed do not touch each other. It is assumed that the intervening spaces are occupied by an imponderable medium, called the luminous ether.

Q. *How do the undulations of ether produce LIGHT?*

A. In the same way as *undulations of air produce sounds*: i. e. by registering themselves upon the extremities of a nerve prepared for their perception.

The term undulatory is not very correct when applied to the motion of air and ether, in the phenomena of sound and light. It is rather *vibratory* than undulatory.

Q. *How FAST does LIGHT TRAVEL?*

A. All light travels so fast, that it would go eight times round the earth, while a person counts "ONE."

All light; whether the light of the sun, the light of a candle, or the *reflected* light of houses, trees, and fields, travels in round numbers 192,000 miles per second.

Q. *Why are SOME surfaces BRILLIANT (like glass and steel,) and OTHERS DULL, like lead?*

A. Because some surfaces *reflect* much *light*, and are *brilliant*; while others *absorb* a great part of it, and appear *dull*.

Q. *Why can a THOUSAND persons SEE the SAME OBJECT at the same time?*

A. Because it throws off from its surface an infinite number of rays in all directions; and one person sees by *one*



portion of these rays, and another person by another.

Q. *Why is the EYE PAINED by a sudden LIGHT?*

A. Because the nerve of the eye is *burdened with rays*, before the pupil has had time to contract.

Q. *Why does it give us PAIN, if a CANDLE be brought suddenly towards our BED at night-time?*

A. Because the *pupil* of the eye *dilates* very much in the dark, in order to *admit more rays*. When, therefore, a candle is brought suddenly before us, the enlarged pupils allow the optic nerves to be overloaded *with rays*, and this causes pain.

Q. *Why CAN we BEAR the candle-light after a few moments?*

A. Because the pupils *contract again* almost instantly; and adjust themselves to the quantity of light, which falls upon them.

Q. *Why can we SEE NOTHING, when we leave a WELL-LIGHTED room, and go into the DARKER ROAD or STREET?*

A. Because the pupil (which *contracted* in the bright room) does not

*dilate instantaneously*; and the contracted pupil is not able to collect rays enough from the darker road or street, to enable us to see objects before us.

Q. *Why do we SEE BETTER, when we get USED to the DARK?*

A. Because the pupil *dilates* again, and allows more rays to pass through its aperture; in consequence of which, we see more distinctly.

Q. *If we look at the SUN for a few moments, why do all OTHER things appear DARK?*

A. Because the pupil of the eye becomes so much *contracted* by looking at the sun that it is *too small* to collect sufficient rays from *other objects*, to enable us to distinguish their colours. (See "*Accidental colours*;" pp. 424, 425.)

Q. *If we watch a bright FIRE for a few moments, why does the ROOM seem DARK?*

A. Because the pupil of the eye becomes so much *contracted* by looking at the fire, that it is *too small* to collect sufficient rays from the objects around, to enable us to distinguish their colours.

Q. *Why can we see the PROPER COLOURS of every object again, after a few minutes ?*

A. Because the pupil dilates again, and accommodates itself to the light around.

Q. *Why can TIGERS, CATS, and OWLS, see in the DARK ?*

A. Because they have the power of *enlarging the pupil of their eyes*, so as to collect scattered rays of light more abundantly : in consequence of which, they can *see distinctly* when it is not light enough for us to see *any thing at all*.

Q. *Why do CATS and OWLS SLEEP almost all DAY ?*

A. Because the pupil of their eyes is *very broad*, and daylight *fatigues* them ; so, they close their eyes for relief.

Q. *Why do CATS blink when they sit before a FIRE ?*

A. Because the pupil of their eye is *very broad*, and the light of the fire is painful ; so they keep shutting their eyes, to relieve the sensation of too much light.

Q. *Why do TIGERS, CATS, OWLS, &c., PROWL by NIGHT for prey ?*

A. Because they *sleep* all *day*, when the strong light would be painful to them; and as they can see clearly in the *dark*, they prowl then for prey.

Q. *Why do GLOW-WORMS glisten by NIGHT only?*

A. Because the light of day is *so strong*, as to *eclipse* their feeble light: in consequence of which, they are *invisible by day*.

Q. *Why can we NOT see the STARS in the DAY-TIME?*

A. Because the light of day is *so powerful*, as to *eclipse* the feeble light of the stars: in consequence of which, they are invisible by day.

Q. *Why can we see the STARS even at MID-DAY, from the bottom of a deep WELL?*

A. Because their light is no longer overpowered by the rays of the sun, which are lost in numerous reflections in the well.

The rays of the *sun* will enter the well very *obliquely*; whereas many *stars* will shine *directly over the well*. See pp. 392, 393.

Q. *What is the USE of TWO EYES, since they present only one image of any object?*

A. 1st—To enlarge our field of vision :

2ndly—To increase the distinctness of vision :

3rdly—To diminish the fatigue of vision : and

4thly—To supply the means of sight, if one eye is injured or lost.

Q. *Why do we NOT see things DOUBLE, with TWO EYES ?*

A. Because both images fall on corresponding parts of the two retinæ, which are simultaneously affected.

Persons with oblique vision see double, because both the images looked at, are not painted on points of the retinæ which correspond.

Q. *Why do we SEE ourselves in a GLASS ?*

A. Because the rays of light from our face, on *striking* against the surface of the glass are reflected, or sent back again to our eye.

Q. *Why are the rays of light REFLECTED by a MIRROR ?*

A. Because they cannot *pass through the impenetrable metal* with which the back of the glass is covered ; so they

*rebound back again, just as a marble would, if it were thrown against a wall.*

Q. *When a marble is rolled towards a wall, what is the path THROUGH WHICH IT RUNS called?*

A. The line of INCIDENCE.

Q. *When a marble REBOUNDS back again, what is the path it THEN describes called?*

A. The line of REFLECTION.

See figure on p. 388. If AB be the line of incidence, then BC is the line of reflection: and *vice versa*.

Q. *When the light of our face goes to the GLASS, what is the path through which it goes CALLED?*

A. The line of incidence.

Q. *When the light of our face is reflected BACK again from the mirror, what is this RETURNING path called?*

A. The line of reflection.

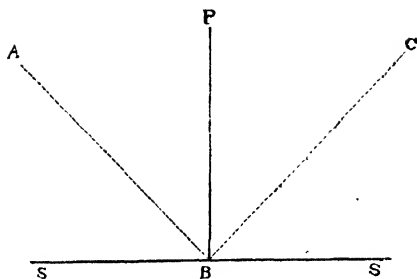
Q. *What is the ANGLE of incidence?*

A. The angle between the line of incidence and the perpendicular.

Q. *What is the ANGLE of reflection?*

A. The angle between the line of reflection and the perpendicular.

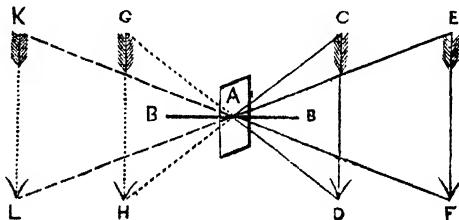
See figure on p. 388.



Let SS be any surface, PB a perpendicular to it.—If a marble were thrown from A to B, and bounded back to C; then ABP would be called the angle of *incidence*, and CBP the angle of *reflection*.

Q. *Why does our reflection in a mirror seem to APPROACH us, as we walk TOWARDS it: and to RETIRE FROM us, as WE retire?*

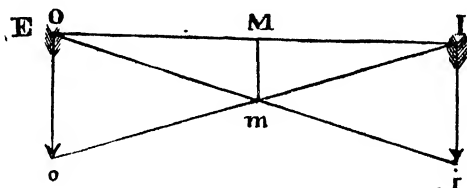
A. Because the lines and *angles of incidence* are always equal to the lines and *angles of reflection*; in consequence of which, the *image* will always seem to be as far *behind* the mirror, as the *real object* is *before* it.



Suppose A to be a mirror—CA, EA, DA, and FA the lines of incidence; then GA, KA, HA, and LA, are the lines of reflection. When the arrow is at CD, its image will appear at GH, because line CA=GA, and line DA=HA; and also the angle CAB=angle GAB, and angle DAB=HAB. For a similar reason, if the arrow were at EF, the image would seem to be at KL.

Q. *Why can a man see his WHOLE PERSON reflected in a LITTLE MIRROR, not 6 inches in length?*

A. Because the *lines and angles of reflection* must be always equal to the *lines and angles of incidence*.

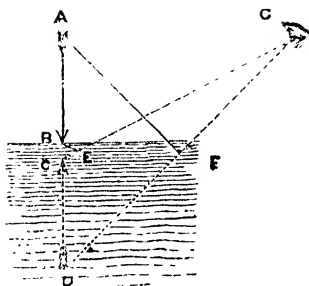


Let M m be a small mirror, and E an eye, looking at I i, an image of the object O o reflected from it. Then the ray which falls perpendicularly from O, is reflected back in the same line, so that the image appears as if placed at I. But the ray which falls obliquely from o to m, is reflected by an equal angle to O, and the image seems to be at i, (i. e. in the line of the last reflection.) Hence the entire image will appear to be as large as I i.

Q. *Why does the IMAGE of any object in WATER always appear INVERTED?*

A. Because the *angles of incidence* are always equal to the *angles of reflection*.





Here the arrow head A strikes the water at F, and is reflected as if from D; and the barb B strikes the water at E, and is reflected as if from C.

If a spectator stands at G, he will see the reflected lines CE and DE, produced as far as G.

It is very plain, that A (the more elevated object) will strike the water, and be projected from it more perpendicularly than the point B; and, therefore, the image will seem inverted. *See p. 388.*

**Q.** *When we see our REFLECTION in WATER, why do we seem to STAND on our HEAD?*

**A.** Because the *angles of incidence* are always equal to the *angles of reflection*.

The feet are nearest to the surface of the water, and must, therefore, seem so in the reflection; and the head which is more remote, must also seem more distant from the surface of the water which reflects it.

**Q.** *Why do WINDOWS seem to BLAZE at SUN-RISE and SUN-SET?*

**A.** Because glass is a good *reflector of light*; and the rays of the sun (striking against the window glass) are *reflected*, or thrown back.

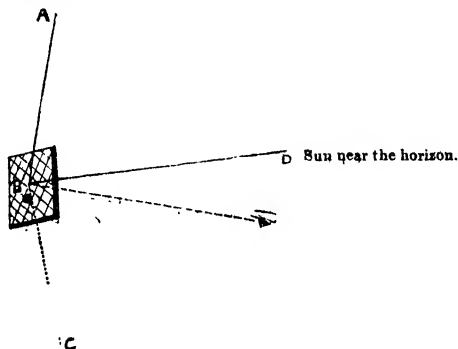
**Q.** *Why do NOT windows reflect the NOON-DAY rays also?*

**A.** They do, but the reflection is *not seen*.

**Q.** *Why is the reflection of the RISING and SETTING sun seen in the window, and NOT that of the NOON-DAY sun?*

**A.** Because the rays of the noon-day sun glance off from the glass downwards, so that an observer could not readily behold both the window and the sun's reflection.

Sun near noon.

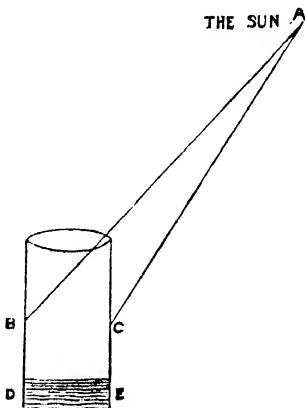


Here AB represents a ray of the noon-day sun striking the window at B; its reflection will be at C:

But DB (a ray of the rising or setting sun) will be reflected to E (the eye of the spectator.)

**Q.** *Why can we not see the sun's reflection in a WELL, during the day-time?*

**A.** Because the rays of the SUN *fall so obliquely*, that they *never reach* the surface of the water at all, but strike against the brick sides.



Let BDEC be the well, and DE the water.

The ray AB strikes against the brick-work *inside* the well: and

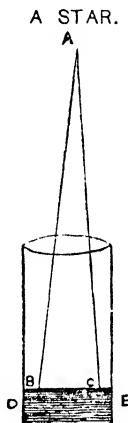
The ray AC strikes against the brick-work *outside* the well.

None will ever touch the water at DE.

**Q.** *Why are STARS, reflected in a WELL, although the SUN is NOT?*

**A.** Because the rays of those STARS, which pass nearly *over-head*, will not fall

so obliquely into the well, as the rays of the sun.



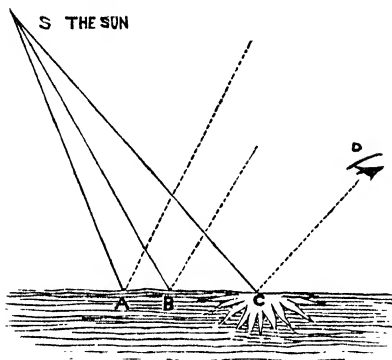
Here the star's rays AB, AC, both strike the water DE, and are reflected by it.

The rays of both sun and moon may be reflected from the surface of water in a well, so placed on the earth's surface, that those luminaries pass vertically overhead (i. e. between the tropics).

*Q. In a sheet of water at noon, the sun appears to shine upon only ONE spot, and all the REST of the water seems DARK,—WHY is this?*

*A. The rays fall at various degrees of obliquity on the water, and are reflected at similar angles; but only those which come from the spot where equal*

angles are formed, between the sun and a perpendicular, and the eye and the same line, are visible as glare.



Here, of the rays SA, SB, and SC, only the ray SC meets the eye of the spectator D. If a line were dropped perpendicularly over C, the angles formed between that line and SC, and DC, would be equal.

The spot C, therefore, will appear luminous to the spectator D, but no other spot of the water ABC

Q. *Why are MORE STARS visible from a MOUNTAIN, than from a PLAIN?*

A. Because they have less *air* to pass through. As air *absorbs* and *diminishes* light; therefore, the *higher* we ascend, the *less light* will be absorbed.

Q. *Why do the SUN and MOON seem LARGER at their RISING and SETTING, than at any other time?*

A. The appearance is an illusion, in consequence of terrestrial objects being placed in close comparison with them at one time and not at the other.

The sun has really the same apparent angular size when on the horizon, and when high in the sky. The moon seems really smaller when on the horizon than when high up.

Q. *Why do the SUN and MOON appear as if flattened into oval forms when seen on the horizon?*

A. Because the lower portions of the disc are more displaced by the refractive power of the atmosphere than the top, so that the vertical diameter is reduced in length. No such reduction takes place in the transverse diameter, therefore the breadth seems longer than the depth.

Q. *How does LIGHT cause the pupil of the eye to CONTRACT?*

A. The pupil of the eye is a round hole, in the midst of a moveable muscular curtain or screen, called the iris. When too much light falls on the nervous retina at the back of the eye, it irritates it; and this irritation is conveyed to the

muscular rings composing the curtain by small nervous fibres, causing them to contract.

The same effect is produced by increasing or diminishing the object aperture of a telescope. The power of a small part of the pupil to allow a perfect but fainter image of an object to be formed, may be thus proved :—Fix the eye attentively upon the flame of a candle, then very slowly advance the edge of a card, held closely to the eye, more and more across the pupil, and the flame will be seen to get fainter and fainter, although it still preserves its perfect outline ; at last, it disappears all at once.

Q. *Why can we NOT SEE into the STREET or road, when candles are lighted ?*

A. Because the pupil of the eye (having become *contracted* by the light of the room) is *too small* to collect rays enough from the dark street, to enable us to see objects in it.

Q. *Why do we often see the FIRE REFLECTED in our parlour WINDOW in winter-time ?*

A. Because glass is a *good reflector* ; and the rays of the fire (striking against the window-glass) are reflected back into the room again.

Q. *Why do we often see several reflections of our FIRE or CANDLES in the window, while we are sitting in our parlour ?*

A. 1st—Because both surfaces of the window glass reflect them : and

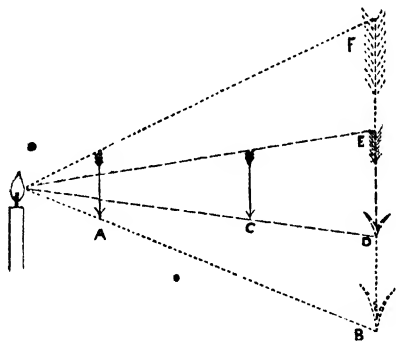
2ndly—The reflections are multiplied by imperfections in the glass.

Q. . WHY is this reflection more clear, if the external AIR be DARK?

A. Because the reflection is not eclipsed by brighter rays, passing through from the other side of the window.

Q. If the SHADOW of an object be thrown on a wall,—the CLOSER the object is held to a CANDLE, the LARGER will be its SHADOW. Why is this?

A. Because the rays of light *diverge* from the flame of a candle in *straight lines*, like lines drawn from the centre of a circle.



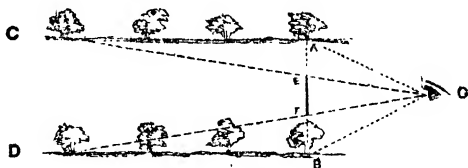
Here the arrow A held close to the candle, will cast the  
M A



shadow BF on a wall; while the same arrow held at C would cast only the little shadow DE.

Q. *Why does an AVENUE of TREES, or a long straight STREET, seem to get NARROWER and narrower in the distance, till the two sides appear to MEET?*

A. Because the *more distant trees or houses are*, the *more acute will be the angle*, that any opposite two make with our eye.

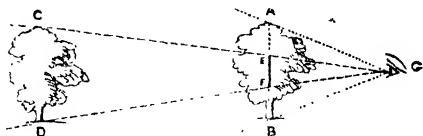


Here the width between the trees A and B will seem to be as great as the line AB:

But the width between the trees C and D will seem to be no more than EF.

Q. *In an AVENUE or long straight STREET, WHY do TREES or houses seem to be SMALLER and smaller as their distance increases?*

A. Because the *more distant trees or houses are*, the *more acute will be the angle* made by their perpendicular height with our eye.



Here the first tree AB will appear the height of the line AB; but the last tree CD will appear only as high as the line EF.

- Q. *Why do some glasses MAGNIFY objects, and others diminish them?*

A. This depends upon the *focus* of the glass; if a glass makes the focal distance of an object *longer*, the object appears *diminished* in size: if shorter, it magnifies.

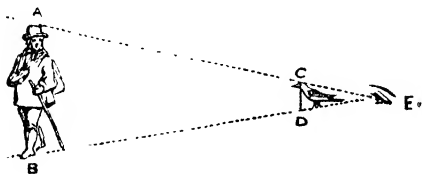
The focal distance means the distance at which the eye perceives an object distinctly. A microscope magnifies by enabling the eye to see an image closer to the eye, than would be possible otherwise.

In the last two figures it is evident—That the larger the angle made by two lines connecting the object with the eye, the larger the object will appear, and *vice versa*. But this angle becomes smaller and smaller as the object is removed further from us. Thus the angle CGD is less than the angle AGB. If a lens therefore *lengthens* the focus, it diminishes objects; if it *shortens* the focus it magnifies them.

- Q. *Why does a man on the TOP of a MOUNTAIN or church spire, seem to be no BIGGER than a crow?*

A. Because the angles made in our eye by the *perpendicular height of a man*

at that distance, is no bigger than that made by a crow close by.

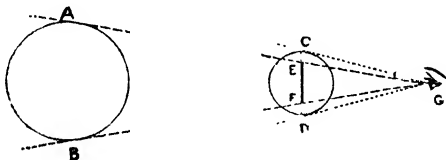


Let AB be a man on a distant mountain or spire, and CD a crow close by :

The man will appear only as high as the line CD, which is the height of the crow.

Q. *Why does the MOON appear to us so much LARGER than the STARS, though in fact it is a great deal SMALLER ?*

A. Because the moon is *very much nearer to us*, than any of the stars.



Let AB represent a fixed star, and CD the moon.

AB though much the larger body, will appear no bigger than EF; whereas the moon (CD) will appear as large as the line CD to the spectator G.

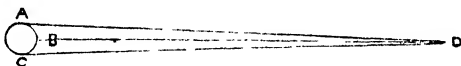
The moon is 240,000 miles from the earth, not quite a quarter of a million of miles. The nearest fixed stars are 20,000,000,000 000. (i.e. 20 billions.)

If a ball went 500 miles an hour, it would reach the moon in twenty days: but it would not reach the nearest fixed star in

4,500,000 years. Had it begun, therefore, when Adam was created, it would be no further on its journey, than a coach (which has to go from the Land's End, Cornwall, to the most northern parts of Scotland) after it has past about three-quarters of a mile.

Q. *Why do the SUN and MOON (which are spheres) appear to be flat surfaces?*

A. Because they are such an *immense way off*, that we can discern *no difference of length*, between those rays which issue from the *edge*, and those which issue from the *centre* of these bodies.



The rays AD and CD appear to be no longer, than the ray BD; but if all the rays seem of the same length, the part B will not seem to be nearer to us than A and C; and, therefore, ABC will look like a flat or straight line.

The rays AD and CD, in the case of the moon, are 240,000 miles long.

The ray BD is 238,910 miles long.

Q. *Why does DISTANCE make an object INVISIBLE?*

A. Because no *visible perpendicular* can be inserted between the lines which form the angle: or because the *light* has been made very *faint* by the distance.

The image formed within the eye, falls upon so small an area of the internal membrane, that this is not able to effect its perception; or it stimulates that area so faintly, that no sense of sight follows.

Q. *Why do TELESCOPES enable us to see objects INVISIBLE to the naked eye ?*

A. Because they gather together more luminous rays from obscure objects, than the *eye* can ; and form a bright image of them in the tube of the telescope, where they are magnified.

As many times as the dimensions of the *object-glass* exceed the dimensions of the *pupil of the eye* ; so many times the penetrating powers of the telescope, will exceed that of the naked eye.

Q. *When a SHIP (out at sea) is approaching shore, why do we SEE the small MASTS, before we see the bulky HULL ?*

A. Because the *earth is round* ; and the *curve* of the sea *hides the hull* from our eyes, after the tall *masts* have become visible.



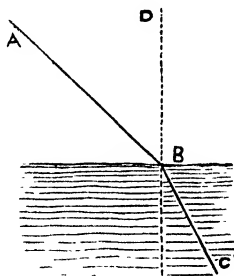
Here only that part of the ship above the line AC, can be seen by the spectator A ; the rest of the ship is hidden by the swell of the curve DE.

Q. *What is meant by REFRACTION ?*

A. *Bending a ray of light*, as it passes from one medium to another.

**Q.** How is a ray of light **BENT**, when it passes from one medium to another?

**A.** When a ray of light passes into a *denser* medium, it is bent *towards* the perpendicular. When it passes into a *rarer* medium, it is bent *from* the perpendicular.



Suppose DE to be a perpendicular line.

If AB (a ray of light) enters the water, it will be bent *towards* the perpendicular to C.

If (on the other hand) CB (a ray of light) emerges from the water, it would be bent *away from* the perpendicular towards A.

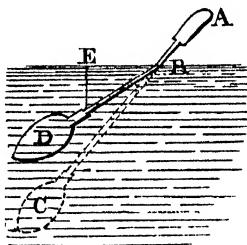
**Q.** If light and sound are both produced by oscillations, why can we not see light, as well as hear sounds, through a bent trumpet or horn?

**A.** Because many substances reflect the oscillations of sound, that do not reflect the oscillations of light.

Intervening angles obstruct the passage of sound in some measure, but not to the same extent as they obstruct the passage of light. Thus if a card be placed between a vibrating tuning fork and the air, the sound is dulled. On the other hand, light may be transmitted through a bent tube, if reflecting mirrors are properly placed at the angles.

Q. *Why does a SPOON (in a glass of water) always appear BENT?*

A. Because the light (reflected from the spoon) is *refracted*, as it emerges from the water.



Here the spoon ABC is refracted, when it enters the water, and appears broken as ABD.

A common experiment, bearing a similar explanation, is this: Put a shilling in an empty basin—move away till you just lose sight of the coin—let some one pour clean water in the basin, and the shilling will again become visible to you.

Q. *Why does a river always appear more shallow, than it really is?*

A. Because the light of the bottom of the river is REFRACTED, as it emerges out of the water.

*See fig. on p. 404.* The bottom of the river will appear elevated, like the bowl of the spoon D.

Q. *How much deeper is a river, than it seems to be?*

A. About one-third. If, therefore, a river seems only 4 feet deep, it is in reality nearly 6 feet deep.

The exact apparent depth would be  $4\frac{1}{3}$ . To find the real depth, multiply by 4 and divide by 3—thus  $4\frac{1}{3} \times 4 \div 3 = 6$  feet real depth.

N. B. Many boys get out of their depth in bathing, in consequence of this deception. Remember, a river is always one-third deeper than it appears to be:—thus, if a river seems to be 4 feet deep, it is in reality nearly 6 feet deep, and so on.

Q. *Why do fishes seem to be nearer the surface of a river, than they really are?*

A. Because the rays of light from the fish are *refracted*, as they emerge from the water: In consequence of which, the fish appear nearer to our eye, than they really are.

*See fig. on p. 404.*

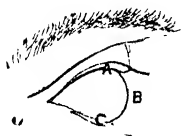
Q. *Why are some persons NEAR-SIGHTED?*

A. Because the COR'NEA of their eye is so *prominent*, that the image of distant objects is formed *before it reaches the RET'INA*; and therefore, is not distinctly seen.



Q. *What is meant by the "COR'NEA of the EYE?"*

A. All the transparent part of the front of the eye-ball.



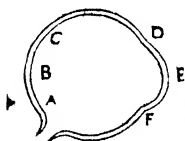
The curve ABC is called the COR'NEA.

If this curve be too prominent (or convex), the eye is near-sighted.

If too flat (or concave), the eye is far-sighted.

Q. *What is meant by the "RET'INA of the EYE?"*

A. The net-work, which lines the back of the eye, is called the retina.



The net-work ABC is called the ret'ina, and the projecting part DEF is called the cor'nea.

N. B. This net-work is composed of a spreading out of the fibres of the nerve of vision.

The eye is covered with a tough pearly opaque membrane, called the *sclerot'ric* coat, going all round the eye except over the front DEF (the cornea); at D and F it terminates and makes a groove, into which the transparent cornea fits, just as a watch glass fits into the metal rim made to receive it.

The opening just below A is the optic nerve, which enters the eye on that side nearest the nose; and after it gets into the eye, expands into the lining called the retina.

Q. *What sort of GLASSES do NEAR-SIGHTED persons wear?*

A. If the cor'nea be *too convex* (or

projecting), the person must wear double concave glasses, to counteract it.

Q. *What is meant by* "DOUBLE CONCAVE GLASSES?"

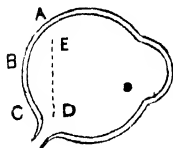
A. Glasses hollowed-in *on both sides*.



The figure A is double concave, or concave on both sides.

Q. *Where is the IMAGE of objects formed, if the cornea be too convex?*

A. If the cor'nea be *too convex*, the image of a distant object is formed in the *vitreous humours* of the eye, and not on the *ret'ina*.



Thus the image is formed at DE; and not on ABC (the retina.)

Q. *What is the use of* DOUBLE CONCAVE SPECTACLE glasses?

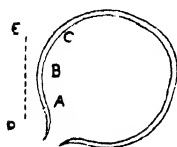
A. To cast the image further back; in order that it may be thrown upon the retina and become visible.

Q. *Why are OLD people FAR-SIGHTED ?*

A. Because the humours of their eyes are *dried up by age*; in consequence of which, the COR'NEA *sinks in*, or becomes flattened.

Q. *Why does the FLATTENING of the COR'NEA prevent persons seeing objects which are NEAR ?*

A. Because the cor'nea is *too flat*; and the image of any near object is not *completely* formed, when its ray reach the RET'INA; in consequence of which, the image is imperfect and confused.



The perfect image would be made at DE; and not on ABC (the retina).

Q. *What sort of GLASSES do' OLD people WEAR ?*

A. As their cor'nea is *not sufficiently convex*, they must use *double convex glasses*, to enable them to see objects near at hand.

Q. *What sort of glasses are "DOUBLE CONVEX SPECTACLE GLASSES?"*

A. Glasses which *curve outwards* on both sides.



The figure A is double convex, or convex on both sides.

Q. *What is the use of* DOUBLE CONVEX *spectacle glasses?*

A. To *shorten the focus of the eye*; and bring the image of distant objects upon the retina.

Q. *Why do* NEAR-SIGHTED *persons bring objects CLOSE to the eye, in order to SEE THEM?*

A. Because the refracting powers of *their eye are so great*, that the image of distant objects is formed in *front* of the *retina*: but when objects are brought *near to the eye*, their image is thrown *further back*, and made to fall on the *retina*.

Because then the rays which come from them to the eye are more divergent, and, therefore, require more refracting power to bring them to a *focus*.

Q. *Why do* OLD *people* HOLD *objects FAR OFF, in order to see them better?*

A. Because the refracting powers of

*their eyes are not great enough*: when, however, objects are held further off, it compensates for this defect; and a perfect image is formed on the retina.

Q. *Why are HAWKS able to see such an IMMENSE way off?*

A. Because they have a muscle in the eye, which enables them to *flatten their cor'nea*, by drawing back the crystalline lens.

There is yet some little uncertainty as to the cause by which the eye is enabled to adapt itself to varying distances.

Q. *Why can HAWKS see objects within half-an-inch of their eyes, as well as those a long way off?*

A. Because their eyes are furnished with a flexible bony rim; which can throw the *cor'nea forward*, and make the hawk near-sighted. (See p. 405.)

Q. *Into how many PARTS may a RAY of LIGHT be DIVIDED?*

A. Into three parts; BLUE, YELLOW, and RED.

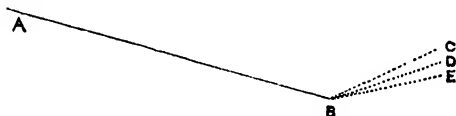
N. B. These three colours by combination, make seven. 1.—RED. 2.—ORANGE (or red and yellow). 3.—YELLOW. 4.—GREEN (or yellow and blue). 5.—BLUE. 6.—INDIGO (a shade of blue); and 7.—VIOLET (or blue and red).

Q. *How is it known, that a ray of light consists of several different colours?*

A. Because a triangular piece of glass (called a prism), will *divide* it into these seven colours: 1.—Red; 2.—Orange; 3.—Yellow; 4.—Green; 5.—Blue; 6.—Indigo; and 7.—Violet.

Q. *Why does a PRISM DIVIDE a ray of light into VARIOUS COLOURS?*

A. Because all these colours have *different refractive susceptibilities*. Red is refracted *least*, and blue the *most*; therefore, the *blue* colour of the ray will be bent to the *top* of the prism, and the *red* will remain at the *bottom*.



Here the ray AB (received on a prism at B), would have the blue part bent up to C; the yellow part to D; and the red part no further than E.

Q. *What is meant by the REFRACTION of a ray?*

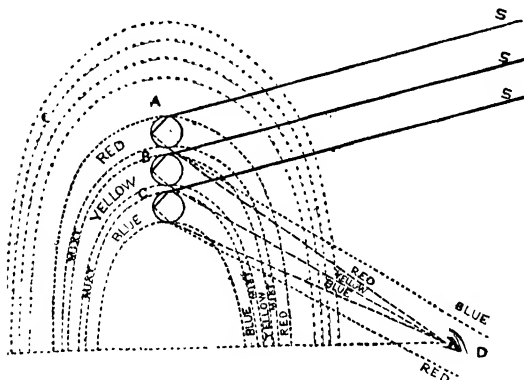
A. *Bending it from its straight line.*

Thus the ray AB of the last figure is refracted at B into three courses, C, D, and E.

Q. *What is the cause of a RAINBOW?*

A. When the clouds opposite the sun

*are very dark, and rain is still falling from them, the rays of the bright sun are divided into colours by the rain-drops, as they would be by a prism.*



Let A, B, and C be three drops of rain; SA, SB, and SC, three rays of the sun. They are all divided into three colours, by the drops of rain on which they fall, and are reflected towards the eye at D.

But since the coloured rays are bent in different degrees, and the drops placed at different heights, only one colour from each enters the eye.

Hence the eye receives the least refrangible (red) from A; the next least (yellow) from B; and the most refrangible (blue) from C. As, however, many drops are similarly circumstanced with regard to the eye, arched bands of colours are visible, constituting the rain-bow.

**Q.** *Does EVERY person see the SAME colours from the SAME DROPS ?*

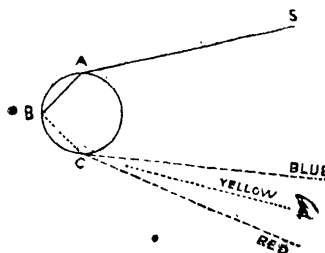
A. No; *no two persons see the same rainbow.*

To another spectator the rays from SB might be *red*, instead of yellow: the ray from SC, yellow; and the blue might be reflected from some drop below C. To a *third* person the red may issue from a drop above A, and then A would reflect the yellow, and B the blue, and so on.

Q. *Why are there often TWO RAINBOWS, at one and the same time?*

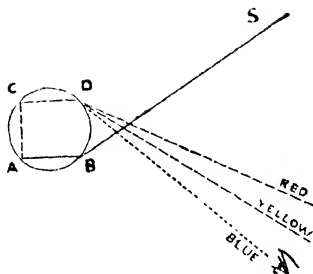
A. In *one* rainbow we see the rays of the sun *entering the rain-drops at the top*, and reflected to the eye *from the bottom*.

In the *other* rainbow, we see the rays of the sun *entering the rain-drops at the bottom*, and reflected to the top, whence they reach the eye.



Here the ray SA (of the primary rainbow) strikes the drop at *A*—is refracted or bent to B,—is then reflected to C, where it is refracted again, and reaches the eye of the spectator.





Here the ray SB (of the secondary rainbow) strikes the drop at B,—is refracted to A,—is then reflected to C,—is again reflected to D, when it is again refracted or bent, till it reaches the eye of the spectator.

Q. *Why are the COLOURS of the SECOND bow all REVERSED ?*

A. Because in *one* bow we see the rays, which enter at the *top* of the rain-drops, *refracted from the bottom* :

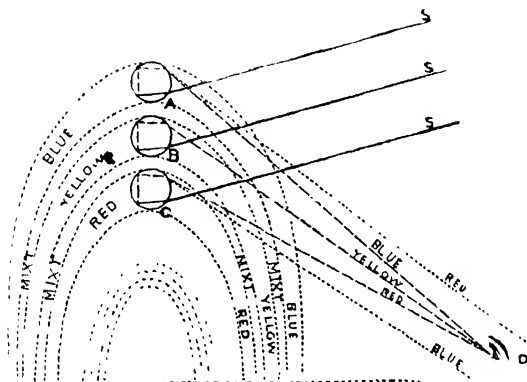
But in the *other* bow we see the rays, which enter at the *bottom* of the rain-drops (after two reflections) *refracted from the top*.

*See figure on next page.*

Here ABC represent three drops of rain in the SECONDARY (or upper) RAINBOW.

The *least* refracted line is RED, and BLUE the *most*.

So the BLUE (or *most* refracted rays) of all the drops in the position of A,—the YELLOW of those in the position of B,—and



the RED (or the *least* refracted rays) of the lowest drops, all meet the eye D, and form a rainbow to the spectator.

The reason why the primary bow exhibits the stronger colours is this—because the colours are seen after *one* reflection and *two* refractions; but the colours of the secondary (or upper) rainbow, undergo *two* reflections and *two* refractions.

(See figure on p. 412.) Here also the *least* refracted ray is RED, and the *most* refracted BLUE (as in the former case); but the position of each is reversed.

Q. Why does a SOAP BUBBLE exhibit such a VARIETY of COLOURS?

A. Because the *thickness of the film* through which the rays pass, is constantly varying.

Q. Why does the THICKNESS of the FILM affect the COLOUR of a soap bubble?

A. Because different *degrees of thickness* in the film produce different *powers of refraction*; and, therefore, where the *thickness* of the film varies, different colours reach the eye.

Where a spot on the bubble grows excessively thin, it appears black, because it then transmits all the light and reflects none.

Q. *Why is a SOAP BUBBLE so constantly CHANGING its THICKNESS?*

A. Because water *runs down from the top* to the bottom of the bubble, till the crown becomes so *thin* as to burst.

Q. *Why are SOME things TRANSPARENT?*

A. Because they are so constituted as to allow the vibrations of light to be uniformly transmitted through their substance.

Q. *Why are some things NOT TRANSPARENT?*

A. Because they are so constituted as not to allow the vibrations of light to be transmitted through their substance.

Therefore they are seen by light reflected back from them, instead of allowing other bodies to be seen by light transmitted through them.

Q. *Why are DRY PAPER and calico (which are OPAQUE) made transparent by being OILED?*

A. Because the pores are filled by the oil, which has a different refractive power to the substance of the paper itself:—by this means the substance acquires the property of transmitting vibrations of light.

Q. *Why are SOME things SHINING, and others DULL?*

A. Because some things *reflect* rays, and are *bright*; but others *absorb* them.

Q. *Why do DESERTS DAZZLE from sunshine?*

A. Because each grain of sand *reflects the rays of the sun*, like a mirror.

Q. *Why are the EDGES of CLOUDS more LUMINOUS, than their CENTRES?*

A. Because the *body of vapour* is *thinnest* at the edges of the clouds.

Q. *WHY is a ray of LIGHT composed of VARIOUS COLOURS?*

A. To vary the colour of different objects. If solar light were of *one uniform colour*, all objects would appear of *that one colour*, or else black.

Q. *Some things are of ONE COLOUR, and some of ANOTHER. Explain the cause of this.*

A. Every ray of light is composed of

all the colours of the rainbow ; and *some* things reflect *one of these colours*, and some *another*.

Q. WHY do *some things* reflect ONE COLOUR, and *some* ANOTHER ?

A. Because the *surface* of things is *differently constructed*, both physically and chemically.

As the thickness of a cord affects the tone of it, so the thickness of a lamina affects its colour, as may be seen in a soap bubble. *Thin tight* cords produce sharp shrill sounds, and thin laminæ produce *blue* and *violet* colours. *Thick loose* cords produce deep bass sounds, and thick laminæ *red* colours.

Q. Why is a VIOLET BLUE ?

A. Because the undulations of ether, which touch its surface, are thrown back with the utmost rapidity ; as the undulations of sound from a very thin tight cord of an Æolian harp.

Blue, or rather purple, is the *high treble* vibrations of light, like the upper C in music. In order to produce violet colour, the undulations of ether must be 699 million of millions per second : and in order to make high C in music, a cord must vibrate 516 times per second.

Q. Why is a ROSE RED ?

A. Red is the *deep bass* vibration of ether, in which the undulations are as slow as they possibly can be, in order to be apparent.

Hence the blind man, who said "the deep blast of a trumpet was scarlet," felt an analogy, which science corroborates.

To produce red, the ether must be jerked off the surface of the body at the rate of 477 millions of millions vibrations in a second : and in order to make low C in music, the air must vibrate only 258 times in a second.

Q. *Why is a PRIMROSE YELLOW ?*

A. Yellow is made by the medium vibrations, as the middle C in music.

Q. *Why are some things BLACK, like coals ?*

A. Because their surface will not reflect the undulations of ether which touch it; in consequence of which, they cease.

These surfaces are to *light*, what insonorous substances are to *sound*.

Q. *Why are some things WHITE, like a lily ?*

A. Because their surface is so constructed as to set in motion the undulations of ether, so that all the rays are reflected together, as harmonious tones in a full chord of music.

Q. *Why are FROTH, SPRAY, many CLOUDS, FAT, LIME, THREAD, &c. &c., white ?*

A. Because they consist of an infinite number of little particles piled one upon another, which are able to reflect all the coloured rays.

Q. *Why are BONES white?*

A. Because they are composed of very small straight pipes, capable of reflecting all the colours together: 600 would be no thicker than a hair.

On the colour of snow, sugar, salt, &c., see p. 351.

Q. *Why are the LEAVES of plants green?*

A. Because a peculiar chemical principle, called chlo'rophyll, is formed within their *cells*.

Chlorophyll (*χλωρὸν φύλλον, a green leaf,*) is the green matter of vegetable substances. *Pronounce klo'-ro-fill.*

Q. *Why are leaves a LIGHT green in SPRING?*

A. Because the chlo'rophyll is not fully formed.

Q. *Why do leaves turn BROWN in AUTUMN?*

A. Because the chlo'rophyll undergoes *decay*; and is not replaced as it is in spring.

Q. *Why are plants a PALE YELLOW, when kept in the DARK?*

A. Because chlo'rophyll can be formed only by the agency of the *sun's rays*.

Q. *Why are POTATOES YELLOW?*

A. Because they are grown *under-ground*; and, therefore, can form no chlo'rophyll in their tubers.

Q. *Why are potatoes (which grow EXPOSED to the air and light) GREEN?*

A. Because chlo'rophyll is formed in them, under the influence of the sun's light.

Q. *Why do the STARS TWINKLE?*

A. Because rays of light, proceeding from the same centre of vibration, *destroy each other*, owing to the inequality of their paths, producing recurring periods of *momentary darkness*.

The differing refrangibility of the atmospheric strata passed through, is the principal cause of the inequality in the motion of the successive systems of waves.

The similarity between sound and light has been already adverted to in pp. 418, 419.—In this particular we find another forcible resemblance,—viz.:

I. TWO SOUNDS INTERCEPTING EACH OTHER'S OSCILLATIONS at opposite phases, will BOTH BE SILENCED.

Vibrate a tuning-fork, and hold it over the mouth of a glass beaker, the air will instantly assume sonorous vibrations, and a *tone* will be produced.

Now hold a beaker at right angles to the other, and the musical tone will instantly cease. Withdraw the second glass, and the tone returns. Hold it again at right angles to the other, and the tone is silenced; and this may be repeated several times.

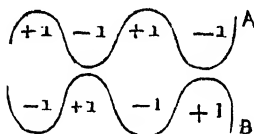
II. So also TWO RAYS OF LIGHT INTERCEPTING EACH OTHER at opposite phases, will PRODUCE DARKNESS.

Because the depression of one set of waves will be exactly measured by the elevation of the other set, and *vice versa*. To explain this:—



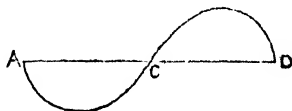


If B were fitted into A, as the depression of B is exactly commensurate with the elevation of A, the two wavy lines would make a level surface.



Again, suppose A the undulations of one star, and B those of another, exactly half a phase different, then it is evident that the elevations and depressions of A would be exactly destroyed by the depressions and elevations of B; and the result of such an interference may be illustrated by the following algebraic formula:

$$\begin{array}{cccc}
 + & - & + & - \\
 - & + & - & + \\
 \hline
 \bullet & \bullet & \bullet & \bullet
 \end{array}$$



Here A D is a wave, A C one phase, C D its opposite phase.

Q. *If you move a stick (burnt at one end) pretty briskly ROUND, it seems to make a CIRCLE OF FIRE,—WHY is this?*

A. Because the eye retains the image

of any bright object, *after the object itself is withdrawn*; and as the spark of the stick returns, *before the image has faded* from the eye, it seems to form a *complete circle*.

Q. *If separate figures (as a man and a horse) be drawn on different sides of a card, and the card TWISTED quickly, the man will seem to be seated on the horse,—WHY is this?*

A. Because the image of the horse *remains upon the eye*, till the man appears.

The Thaumatrope is constructed on this principle; it was invented by Dr. Paris, and consisted at first of a piece of circular card, having two silk strings fastened at the two extremes of its diameter: by twisting the strings, the card is turned round with great rapidity, and the man on one side of the card seems seated on the horse painted on the obverse side. The magnificent con-formations of coloured waves, by the same instrument, is a great improvement on the original toy.

Q. *If we look at a RED-hot FIRE for a few minutes, WHY does every thing seem TINGED with a BLUISH GREEN colour?*

A. Because bluish green is the “ACCIDENTAL COLOUR” of red: If we fix our eye upon *any colour whatsoever*, we see every object tinged with its *accidental colour*, when we turn aside.

“Accidental colour,” see note, p. 425.

Q. *Why does the eye perceive the ACCIDENTAL COLOUR, when the fundamental one is removed?*

A. Because the nerve of the eye has become tired of the one, but still remains fresh for the perception of the other.

Q. *If we wear BLUE GLASSES, why does every thing appear tinged with ORANGE, when we take them off?*

A. Because orange is the “accidental colour” of blue; and if we look through blue glasses, we shall see its “accidental colour,” when we lay our glasses aside.

Q. *If we look at the SUN for a few moments, every thing seems tinged with a VIOLET colour,—WHY is this?*

A. Because violet is the “accidental colour” of yellow; and as the sun is yellow, we shall see its “accidental colour” blue, when we turn from gazing at it.

Q. *Does not the DARK SHADOW (which seems to hang over every thing, after we turn from looking at the sun) arise from our eyes being DAZZLED?*

A. Partly so: the pupil of the eye is very much contracted by the brilliant light of the sun, and does not adjust itself immediately to the feebler light of terrestrial objects; but, independent of this,

the "ACCIDENTAL COLOUR" of the sun being *dark violet*, would tend to throw a shadow upon all things. (*See p. 383.*)

Q. *Why is BLACK glass for spectacles the BEST for wear, in this respect?*

A. Because *white* is the accidental colour of *black*; and if we wear *black glasses*, every thing will appear in *white light*, when we take them off.

Q. *Why does every thing seem shadowed with a BLACK MIST, when we take off our common SPECTACLES?*

A. Because the glasses are *white*; and black being its "accidental colour," every thing appears in a *black shade*, when we lay our glasses down.

|                              |                  |
|------------------------------|------------------|
| The accidental colour of red | is bluish green. |
| " " " of orange              | " blue.          |
| " " " of violet              | " yellow.        |
| " " " of black               | " white.         |

And the converse of this is true:—

|                                       |           |
|---------------------------------------|-----------|
| The accidental colour of bluish green | is red.   |
| " " " of blue                         | " orange. |
| " " " of yellow                       | " violet. |
| " " " of white                        | " black.  |

(The law of an accidental colour is this—The accidental colour is always half the spectrum. Thus, if we take half the length of the spectrum by a pair of compasses, and fix one leg in any colour, the other leg will hit upon its accidental colour.)

N.B. The spectrum means the seven colours (red, orange, yellow, green, blue, indigo, and violet,) divided into seven *equal* bands, and placed side by side in the order just mentioned.

## CHAPTER XXVIII.

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SOUND.

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Q. *How is SOUND produced?*

A. The vibration of some sonorous substance produces a corresponding motion in the air, which strikes upon the *drum of the ear*, and gives the sensation of sound.

Q. *What are MUSICAL SOUNDS?*

A. Regular and uniform successions of vibrations.

Q. *How fast does SOUND TRAVEL?*

A. About 13 miles in a minute, or 1142 feet in a second of time.

Light would go 8 times round the whole earth, while sound is going its 13 miles.

Q. *Why are SOME things sonorous, and others NOT?*

A. The sonorous quality of any substance, is connected with its *hardness and elasticity*.

Q. *Why are COPPER and IRON sonorous, and not LEAD?*

A. Because copper and iron are *hard and elastic*; but lead, being neither hard nor yet elastic, is *not sonorous*.

Q. *Of what is BELL-METAL made?*

A. Of *copper and tin* in the following proportions;—In every 5 pounds of bell-metal, there should be 1 lb. of tin, and 4 lbs. of copper. •

Q. *Why is this mixture of tin and copper used for BELL-METAL?*

A. Because it is much *harder* and more *elastic*, than any of the pure metals.

Q. *Why is the sound of a bell STOPPED, by TOUCHING the bell with our finger?*

A. Because the weight of our finger *stops the vibrations* of the bell; and as soon as the bell *ceases to vibrate*, it ceases to make sound-waves in the air.

Q. *Why does a SPLIT bell make a hoarse disagreeable sound?*

A. Because the *split* of the bell causes a *double vibration*: And as the sound-waves *clash and jar*, they impede each other's motion, and produce discordant sounds.

Q. *Why do FIDDLE-STRINGS give musical sounds?*

A. Because the bow *causes them to vibrate*: and this vibration *sets in motion the sound-waves of the air*, and produces musical notes.

Q. *Why does a DRUM sound?*

A. Because the parchment head of the drum *vibrates* from the blow of the drum-stick, and sets in motion the sound-waves of the air.

Q. *Why do MUSICAL GLASSES give sound?*

A. Because the glasses *vibrate* when they are struck, and set in motion the sound-waves of the air.

Q. *Why do FLUTES, &c. produce musical sounds?*

A. Because the breath of the performer causes the *air in the flute to vibrate*; and this vibration sets in motion the sound-waves of the air.

Q. *Why do PIANO-FORTES produce musical sounds?*

A. Because each *key of the piano* (being struck with the finger) lifts up a little hammer, which *knocks against a*

*string* ; and the vibration thus produced, sets in motion the sound-waves of the air.

Q. *Why are some notes BASS, and some TREBLE ?*

A. Because *slow* vibrations produce *bass or deep sounds* ; but *quick* vibrations produce *shrill or treble ones*.

The deepest bass sound audible is produced by 32 vibrations in a second ; the sharpest treble sound by 15,000.

The note of any higher octave is produced by twice as many vibrations, as the corresponding note of the octave below. Thus if C on the piano be produced by 258 vibrations in a second, then the octave (or eighth note *higher*) would be produced by 516 vibrations in the same time, and the eighth note *lower* by 129 vibrations. (See p. 418.)

Q. *Why is an instrument FLAT, when the strings are UNSTRUNG ?*

A. Because the vibrations being *too slow*, the sounds produced are not *shrill* or *sharp* enough.

Q. *Why can persons, living a mile or two from a town, hear the bells of the town-church SOMETIMES, and not at OTHERS ?*

A. Because fogs, rain, and snow, obstruct the passage of sound ; but when the air is *cold and clear*, sound is propagated more easily.

The direction of the wind will often account for this fact.

Q. *WHY can we NOT hear sounds (as those of*



*distant church bells*) in RAINY or snowy weather, so well as in FINE weather?

A. Because falling rain or snow *interferes with the undulations of the sound-waves*, and stops their progress.

Q. Why can we HEAR distant clocks MOST distinctly in clear COLD weather?

A. Because the air is of more *uniform density*, and there are *fewer currents of air* of unequal temperature to interrupt the sound-waves.

Besides, dense air can propagate sound-waves more readily than rarer air.

Q. Why can persons (near the POLES) hear the VOICES of men in conversation a MILE distant in winter time?

A. Because the air is very *cold, clear, and still*; in consequence of which, there are but *few currents of air* of unequal temperature to interrupt the sound-waves.

Captain Ross heard the voices of his men in conversation a mile and a half from the spot where they stood: and Lieutenant Foster held a conversation with a man across the harbour of Port Bowen, (in the North Sea,) a distance of a mile and a quarter.

Q. Why are not SOUNDS (such as those of *distant church bells*) heard so distinctly on a HOT DAY, as in frosty weather?

A. 1st—Because the density of the air is *less uniform* in very hot weather :

2ndly—It is *more rarefied* ; and consequently, a worse conductor of sound : and

3rdly—It is more liable to *accidental currents*, which impede the progress of sound.

Q. *Why can we not hear sounds (such as those of distant clocks) so distinctly in a thick MIST or HAZE, as in a clear night ?*

A. Because the *density* of the air is not so *uniform* when it is laden with mist ; in consequence of which, its *sound-waves* are obstructed in their progress.

Q. *Why do we hear sounds better by NIGHT, than by DAY ?*

A. 1st—Because night air is of *more uniform density*, and less liable to *accidental currents* : and

2ndly—Night is more *still*, from the suspension of business and the hum of men.

Q. *Why is the air of more UNIFORM density by NIGHT, than it is by day ?*

A. Because the breezes (created by

the action of the sun's rays) generally cease at night-fall.

Q. *How should PARTITION WALLS be made, to PREVENT the voices in adjoining rooms from being heard?*

A. The space between the laths (or canvass) should be filled with *shavings* (or *saw-dust*;) and then no sound would pass from one room to another.

Q. *Why would shavings, or saw-dust, PREVENT the transmission of sound from room to room?*

A. Because there would be *several different media* for the sound to pass through: 1st—the air; 2ndly—the laths and paper: 3rdly—the saw-dust or shavings: 4thly—lath and paper again: 5thly—the air again: and every change of medium resists the progress of the *sound-waves*.

Q. *Why can DEAF people hear through an EAR TRUMPET?*

A. Because it restrains *the spread of the voice*, and limits the *diameter of the sound-waves*; in consequence of which, their *strength* is increased.

Q. *Why are MOUNTAINS noiseless and quiet?*

A. Because the air of mountains is *very rarefied*; and rarefied air is a bad medium for conducting sound.

On the other hand, slight sounds in a diving-bell, when the air is much condensed by the upward pressure of the water, are very intense, and sometimes even painful.

Q. *How do you know, that the rarity of air DIMINISHES the intensity of sound?*

A. If a bell be rung in the receiver of an air-pump, the sound becomes *fainter and fainter*, as the air is exhausted; till at last it is almost *inaudible*.

Q. *What is the cause of ECHO?*

A. Whenever a sound-wave strikes against any *obstacle* (such as a wall or hill), *it is reflected* (or thrown back); and this *reflected sound* is called an ECHO.

The same laws govern echo as light. (*See p. 387.*)

Q. *What places are most famous for ECHO?*

A. Caverns, grottoes, and ruined abbeys; the areas of halls; the windings of long passages; the aisles of cathedral churches; mountains, and icebergs.

Q. *Why are caverns, and grottoes, FAMOUS for ECHOES?*

A. Because the sound-waves which

cannot pass through the cavern or grotto, are driven back again from their sides.

Q. *Why are halls, winding passages, ruins, and cathedral aisles, FAMOUS for ECHOES?*

A. Because the sound-waves *cannot flow freely forward* in them: but strike against the opposing walls and are beaten back.

Q.\* *Why are MOUNTAINS and ice-bergs FAMOUS for ECHOES?*

A. Because they present an insurmountable *barrier* to the sound-waves, and *throw them back again*.

Q. *Why do not the WALLS of an ordinary ROOM or small church produce perceptible ECHO?*

A. Because sound travels with such *velocity*, that the echo is *blended with the original sound*; and the two produce but *one impression* on the air.

Sound travels 13 miles in a minute; and no perfect echo is heard, unless the surface (against which the sound strikes) is 65 feet from the place, whence the sound originally proceeded.

Q. *Why do very LARGE buildings (as cathedrals), often REVERBERATE the voice of the speaker?*

A. Because the walls are so *far off from the speaker*, that the echo does not *get back in time* to blend with the original

sound; and, therefore, *each* is heard separately.

Q. *Why do SOME echoes repeat only ONE syllable?*

A. Because the echoing body is very *near*. The *further* the echoing body is off, the more syllables it will *reflect*: If, therefore, it be very *near*, it will repeat but one syllable.

Q. *Why does an ECHO sometimes repeat TWO or more syllables?*

A. Because the echoing body is *far off*; and there is time for one reflection *to pass away*, before *another* reaches the ear.

N.B. All the syllables must be *uttered*, before the echo of the first syllable reaches the ear—If, therefore, a person repeats 7 syllables in 2 seconds of time, and hears them *all* echoed, the reflecting object is 1142 feet distant; (because sound travels 1142 feet in a second, and the words take one second to *go to* the reflecting object, and one second to *return*).

Q. *Why are TWO or more ECHOES sometimes heard?*

A. Because separate reverberating surfaces receive the sound, and reflect it in succession.

17 miles above Glasgow (Scotland) near a mansion called Rosneath, is a very remarkable echo. If a trumpeter plays a tune,

the echo will begin the same tune and repeat it all accurately :— as soon as this echo has ceased, *another* will echo the same tune in a lower tone ; and after the second echo has ceased, a *third* will succeed with equal fidelity, though in a much feebler tone.

At the Lake of Killarney in IRELAND, there is an echo, which plays an excellent "*second*" to any simple tune played on a bugle.

Q. *Why do WINDOWS RATTLE when CARTS pass by a house ?*

A. 1st—Because glass is *sonorous* ; and the air communicates its vibrations to the glass, which echoes the same sound : and

2ndly—The *window-frame* being *shaken*, contribute to the noise.

Window frames are shaken, 1.—By sound-waves impinging against them ; 2.—By a vibratory motion communicated to them by the walls of the house.

## CHAPTER XXIV.

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## MISCELLANEOUS.

Q. *Why do the BUBBLES in a CUP of TEA range round the SIDES of the CUP ?*

A. Because the cup *attracts* them.

Q. *Why do all the LITTLE BUBBLES tend towards the LARGE ones?*

A. Because the large bubbles (being the superior masses) *attract them.*

Q. *Why do the BUBBLES of a CUP OF TEA FOLLOW a TEA-SPOON?*

A. Because the tea-spoon *attracts them.*

Q. *Why are the SIDES of a pond covered with LEAVES, while the MIDDLE of the pond is quite CLEAR?*

A. Because the shore *attracts the leaves to itself.*

If there be any wind stirring it will drive floating bodies to one side, independently of this attractive force.

Q. *Why do all fruits, &c. (when severed from the tree) FALL to the EARTH?*

A. Because the earth *attracts them.*

Q. *Why do persons (who water PLANTS) very often pour the water into the SAUCER, and not over the PLANTS?*

A. Because the water in the saucer is *drawn up* by the mould (through the hole at the bottom of the flower-pot) and transferred through the root to the stem and leaves of the plant by CAPILLARY ATTRACTION. (See p. 76.)



Q. *Why is vegetation on the MARGIN of a RIVER more LUXURIANT, than in an open FIELD?*

A. Because the porous earth on the bank *draws up water* to the roots of the plants by CAPILLARY ATTRACTION.

Q. *Why is a LUMP of SUGAR (left at the bottom of a cup) so LONG in MELTING?*

A. Because (as it melts) it makes the tea around it *heavier*; and (so long as it remains at the bottom) is surrounded by tea fully *saturated* with sugar; in consequence of which, the *same* portions of liquid will hold *no more sugar in solution*.

Q. *Why does a LUMP of SUGAR MELT more QUICKLY, when STIRRED ABOUT?*

A. Because *fresh portions of unsaturated tea* come in contact with the lump, and soon dissolve it.

Q. *Why does a PIECE OF SUGAR (held in a spoon at the TOP of our tea) melt very RAPIDLY?*

A. Because, as the tea becomes *sweetened*, it *descends to the bottom of the cup* by its own gravity; and *fresh portions of unsweetened tea* are brought constantly into contact with the sugar, till the lump is entirely dissolved.

Q. *How can a SICK ROOM be kept FREE from unhealthy EFFLUVIA?*

A. By sprinkling it with a solution of chloride of lime.

Q. *Why is CHLORIDE of LIME used to fumigate a sick room?*

A. Because the chlorine absorbs the *noxious gases of the confined air*; and by this means removes both the *offensive smell*, and the *infection* of a sick room.

Q. *Why does LIME destroy the offensive smells of BINS, SEWERS, &c.?*

A. Because it decomposes the offensive gases upon which the smell depends, and destroys them, by chemical union.

Q. *How can the TAIN of MEAT be removed?*

A. Either by washing with PYROLIGNEOUS ACID,—or by covering the meat for a few hours with common CHARCOAL,—or by putting a few lumps of charcoal into the water in which it was boiled.

Q. *Why do these things DESTROY the TAIN of meat?*

A. Because they combine with the putrescent particles, and neutralize their offensive taste and smell.

Q. *Why should* BED-ROOMS, COTTAGES, HOSPITALS, *and* STABLES, *be washed occasionally with* LIME-WHITE ?

A. Because lime is *very caustic*, and removes all organic matters adhering to the walls.

Q. *Why is a* DEAD man TALLER *than a living one ?*

A. Because at death the CARTILAGES are *relaxed*. So, also, after a night's rest, a man is *taller* than when he went to bed.

Q. *What is* SLEEP ?

A. Sleep is the *rest of the brain*, and the sensitive and motor parts of the *nervous system*.

“Motor” (from the Latin *moveo* to move) those parts which are connected with animal motion.

Q. *Why do we not* SEE, *when we are asleep with our* EYES OPEN ?

A. Because the “RET’INA of the eye” is *inactive* and at rest. (See p. 406.)

Q. *Why do we not* HEAR *in sleep ?*

A. Because the nerve of hearing (seated within the TYMPANUM of the ear) is at rest.

Q. *Why do we not TASTE, when we are asleep?*

A. Because the nerves at the end of the tongue (called papillæ) are inactive and at rest.

Q. *Why do we not FEEL, when we are asleep?*

A. Because the ends of the nerves (called papillæ) situated in the skin, are inactive and at rest.

Some of the phenomena of dreaming seem to show that the functions of the organs of sense are performed. It is the power of perception rather than that is dormant.

Q. *Why have persons in sleep no WILL of their own, but may be moved at the will of ANY one?*

A. Because the entire nervous system, upon some of whose functions the exercise of will depends, is inactive and at rest.

Q. *Why has a DREAMER no power of JUDGMENT or REASON?*

A. Because the parts of the brain concerned in the performance of these functions are inactive and at rest.

Q. *Why does a person FEEL, when he is TOUCHED?*

A. Because the ends of certain nerves which terminate in the skin, are excited;

and this produces a nervous sensation, called FEELING.

The terminations of the nerves mentioned are called "Papillæ."

Q. *Why are persons able to TASTE DIFFERENT FLAVOURS ?*

A. Because the "PAPILLÆ" of the tongue and palate are *excited*, when food touches them; and this produces a nervous sensation, called TASTE.

Q. *What is the use of Saliva ?*

A. 1st—It mixes *mechanically* with our food, reducing it to a soft pulpy state: and

2ndly—It has certain *chemical* properties, which greatly assist digestion.

Q. *Why does the savour of delicious food make the MOUTH of a hungry man WATER ?*

A. Because the salivary glands are excited by the savour of the food.

This is a wise provision of God, who thus excites the flow of saliva by the odour of the food, before it is needful to masticate and swallow it.

Q. *Why is SALIVA FROTHY ?*

A. Because it contains *air*, in order that it may introduce *oxygen* into the stomach.

## APPENDIX OF MISCELLANEOUS QUESTIONS

*For the ingenious reader to solve.*

The figures refer to the page, where some cognate question may be found.

1. Why does *abundance* of dew in the morning indicate that the day will be *fine*? p. 211.
2. Why does an *oar* in water appear *bent*? p. 404.
3. If a piece of *brown* paper be submitted to the action of a *burning-glass*, it will catch fire much *sooner* than a piece of *white* paper would: Why so? p. 195.
4. Why does a *blue* dress appear *green* by *candle-light*? p. 47.
5. Why does the *sun* look *red* in a *fog*? p. 145.
6. An *ink-spot* on linen is first *black*, why does it afterwards turn *yellow*? p. 419.
7. Why is it dangerous, to row a boat under a bridge?
8. Why does a *candle flicker*, especially just previous to its being *burnt out*? pp. 80.
9. If the "copper" (or boiler) attached to a kitchen range, be filled with cold water *after* the fire has been lighted some time, it will very often *burst*: Why? pp. 126, 127.
10. Why do all things appear *black* in the *dark*? p. 418.
11. Why are the *flag-stones* of our streets frequently *loosened* after a *frost*? p. 367.
12. Why is a *room warmer*, when the window curtains are drawn? pp. 182, 183.
13. Why are rooms much *warmer* for being furnished with *double doors and windows*, like Kensington Palace? pp. 182, 183.
14. Why is *loose clothing warmer*, than that which fits close? p. 183.
15. Why does *wetting* a *cornelian* make it more *transparent*? p. 421.
16. Why does *painting iron* prevent it from *rusting*? p. 259.
17. Why is a *dull fire revived* by sweeping clean the hobs, bars, ash-grate, &c. of the stove? pp. 52, 53.
18. Why does *stirring* a *dull fire* serve to quicken it? pp. 52, 53.
19. Why does *soapy water* "lather"? p. 365.
20. Why is well-made *bread* full of holes or *eyes*? p. 288.
21. Why do the *sails* of a *wind-mill* turn round? p. 113.
22. If you strike a finger-glass, why is the *sound silenced* by *touching* the glass with your finger? p. 426.
23. Why does a *wet sponge* clean a *slate*? p. 362.

## 444 MISCELLANEOUS QUESTIONS.

24. Why do *stars twinkle* more than usual, just previous to rain? *p.* 421.
25. Why does *milk boil over*, more readily than water? *p.* 365.
26. If a *picture* be *glazed*, you cannot see it in certain positions—Why not? *p.* 396.
27. *Dust* very rarely flies by *night*—Why so? *pp.* 227.
28. Why does the *cork* of a *soda-water* bottle make a loud report, when drawn? *p.* 108.
29. Why does the *cork* of a *soda-water* bottle fly off, as soon as it has been released from the bond which held it in? *p.* 277.
30. Why do our *hands* and *lips chap* in frosty and windy weather? *p.* 333.
31. When a *black subsoil* is dug or ploughed up, it turns of a reddish *brown* after a short time—Why is this? *pp.* 260.
32. Why are *decaying vegetables* always *wet*? *p.* 284.
33. If a house be faced with *stucco* to resemble stone, why does the facing very often *flake off* in winter, and leave the house unsightly? *p.* 375.
34. Why do the *lustres* of a *chandelier* seem tinted with such *various* and beautiful *colours*? *p.* 411.
35. *Horn* is *transparent*, why are *not* *horn shavings* transparent also? *p.* 416.
36. When a glazier is mending a window, and cleans the pane with his brush, why do the loose pieces of putty (on the *opposite* side of the window-pane) *dance* up and down? *p.* 293.
37. When you rub a piece of paper with *Indian rubber*, why is it *sticky*? *p.* 29.
38. If you dry a piece of common *brown paper* by the fire, and draw it once or twice between your two *knees*, why will it *stick* fast to the wall? *p.* 29.
39. Why can persons be *heard* (in a calm day) at a *greater distance* on the *sea*, than on land? *p.* 430.
40. The *height* of *mountains* may be ascertained by a *barometer*: Explain the reason of this. *p.* 335.
41. How does *starch* assist in giving a smooth *glazed surface* to *linen*? *p.* 421.
42. If a *drop* of *water* be spilt on a *table cloth*, why will it *spread* in all directions? *pp.* 76.
43. Why does *salt* *preserve* meat? *p.* 438.
44. Why does melted *wax* become *hard*, when *cold*? *p.* 169.
45. Why does *paint* often *blister* from *heat*? *p.* 375.
46. Why are *rotting leaves* *hot*? *pp.* 58, 283.
47. Why are *rotting leaves* *damp*? *p.* 283.
- 48.

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49. Why are *plants white*, which are kept in the dark ? p. 420.
50. Why does *oil* become *thick* in *winter-time* ?
51. Why does a *pop-gun* make a loud *report*, when the paper bullet is discharged from it ? p. 107.
52. Why does *steam* make the engine of a locomotive *whistle* ? p. 116.
53. Why will *bright iron* lose its *polish*, by being put into a *fire* ? pp. 258.
54. Why does *sound* seem *louder* in *caves*, than on a plain ? p. 431.
55. Why does *point* preserve *wood* ?
56. Why does *mother of pearl* shew so many colours ?
57. Why can you fill a *dry glass* beyond the level of the brim ? p. 436, 437.
58. If you leave a little tea in your cup, and put your spoon in, why does the *tea* rush to the *spoon* ? p. 436.
59. When *liquor* is poured from a bottle, why does it *gurgle* ? p. 287.
60. Why will *lucifer matches* ignite by merely drawing them across any rough surface ? pp. 104, 298.
61. Why will they *not* ignite, if they are *damp* ? p. 45.
62. When our likeness is reflected in a looking glass, the entire image is *reversed*, our *right* cheek is the *left* cheek of the reflection ; if we lift our *right* arm, the reflection moves the *left* arm, and *vice versa*. Why is this ? p. 388.
63. A *silver* tea spoon becomes *more heated* by hot tea, than one of *inferior* metal (as German silver, Nickell, &c.) Why ? p. 172.
64. If you scrape a slip of paper with a knife, why will the paper curl ?
65. Why does the *stopple* of a decanter *stick fast*, if it be put in damp ?
66. Why does the *stopple* of a *smelling bottle* often *stick fast* ?
67. Decaying vegetables are first of a brownish tint, why do they afterwards turn of a *deep black* ?
68. Why is an *oak* struck by *lightning* more frequently than any other tree ?
69. Why does a *lobster*, which is black while alive, turn *red* by being *boiled* ?
70. Why does a shrimp, which is nearly *white* while alive, turn *red* by being *boiled* ?
71. Why is the *shadow* of the *moon* stronger, than the shadow of the sun ?
72. Why does *hartshorn* take out the red spot in cloth, produced by *sulphuric* or any other *acid* ?



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73. Why will *powdered sulphur quench fire*, more rapidly than water?

74. How does *starch* serve to *stiffen* linen?

75. Why should *lightning-conductors* be *pointed*?

76. Why do *bricks* turn *green*, after they have been exposed to the weather?

77. When *potatoes* are boiled, why are those at the *top* of the boiler cooked *sooner*, than those nearer to the fire?

78. If a silver *spoon*, which has been *tarnished* by an *egg*, be rubbed with a little *salt*, why will the tarnish disappear.

79. Why are *books* discoloured by *age* or damp?

80. Why does *sour milk curdle*?

81. Why does *churning* milk, convert it into *butter*?

82. Why does the *sun* or fire *warp* wood?

83. Why does the *sun fade* artificial colours?

84. When a *knife* is sharpened on a *grind-stone*, why is *oil* or water used?

85. Why does *bread* become *mouldy*, after it has been kept a few days?

86. Why does *meat putrefy* sooner in *hot damp* weather, than in cold?

87. Birds, after they are killed, *keep longer* in their *feathers*, than when they are plucked; Why is this?

88. Why do *plants*, which are kept in a window, *bend* to the glass?

89. Why does *Indian-rubber* erase *pencil marks* from paper?

90. Why does *water rot* wood?

91. Why does *water* make a *hissing* noise, when it is poured on fire?

92. Why will *hot* iron *bend* more easily than *cold*?

93. Why does *iron* turn first *red* and then *white* from *heat*?

94. Why does *hot* water *freeze* more quickly than cold?

95. Why does *water freeze* more quickly than *milk*?

96. Why are *glue*, *gum*, *starch*, and *paste* adhesive?

97. Why does a railway *train* make more *noise*, when it passes over a *bridge* or *meadow*, than when it runs over *solid ground*?

98. Why does *milk* *boil* more *quickly* than water?

99. Why will *milk* *burn* more readily than water?

100. Why is it impossible to *write* on *greasy* paper?

101. Why does rain "*bring down* the *cold*"?

102. Why does *turpentine* take out *grease* spots from cloth?

103. Why does *oxalic acid* take out *ink* spots?

104. Why does *waxing* cotton or thread make it *stronger*?

105. Why is a *stick* made *flexible* by *boiling* it?

106. Why does *manure* make land *fertile*?

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